AD-786 544

STUDY OF IMPORTANCE OF BACKWATER CHUTES TO A RIVERINE FISHERY

Harold L. Schramm, Jr., et al

Southern Illinois University

Prepared for:

Army Engineer Waterways Experiment Station

August 1974

DISTRIBUTED BY:

NTIS

National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Contract Report Y-74-4	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER AD-786544
4. TITLE (and Subtitle) STUDY OF IMPORTANCE OF BACKWATER CHUTES TO A RIVERINE FISHERY		5. TYPE OF REPORT & PERIOD COVERED Final report 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Harold L. Schramm, Jr. William M. Lewis		8. CONTRACT OR GRANT NUMBER(s) DACW39-73-C-0015
9. PERFORMING ORGANIZATION NAME AND ADDRESS Fisheries Research Laboratory Southern Illinois University Carbondale, Illinois 62901		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS U. S. Army Engineer District, St. Louis 210 North 12th St. St. Louis, Missouri 63101		12. REPORT DATE August 1974 13. NUMBER OF PAGES
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) U. S. Army Engineer Waterways Experiment Station P. O. Box 631 Vicksburg, Mississippi 39180		15. SECURITY CLASS. (of this report) 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Aquatic biology	Fishes
Backwater areas	Mississippi River
Environmental impact	Rivers

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A comprehensive review was made of the literature to determine the environmental impact of the loss of backwater areas in connection with proposed changes in the channel of the Mississippi River between St. Louis, Missouri, and Cairo, Illinois. The review covered two general areas: literature pertaining to the physical, chemical, and biotic factors of larger rivers, and literature pertaining to the biology of the fishes recorded as present in the section of concern in the Mississippi River. It was found that only a limited

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. ABSTRACT (Continued)

amount of data has been published. The direct effects of the physicochemical factors (current, turbidity, substrate, and dissolved oxygen) were examined. Based on the literature, it was concluded that extra-channel areas provided the most favorable conditions of existence for the fishes recorded as present in the study area. (Extra-channel areas include the complex of habitats classified as side channels, river lakes and ponds, and sloughs.) Identification is made of those specific fish that would and those that would not be affected by the hypothetical physicochemical conditions that would prevail following the loss or alteration of the extra-channel areas.

PREFACE

The work described in this report was performed under Contract DACW 39-73-C-0015, titled "Study of Importance of Backwater Chutes to a Riverine Fishery," dated Sept 1972, between the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi, and the Fisheries Research Laboratory, Southern Illinois University, Carbondale, Illinois.

The report is a review of the literature basic to the preparation of an environmental impact statement in connection with proposed changes in the channel of the Mississippi River between St. Louis, Missouri, and Cairo, Illinois. The report was prepared by Mr. H. L. Schramm, Jr., Research Assistant, and Dr. W. M. Lewis, Director of the Fisheries Research Laboratory, Southern Illinois University.

The contract was monitored by William P. Emge under the general supervision of Dr. John Harrison, Chief, Environmental Effects Laboratory, WES. The Directors of WES during the study and preparation of the report were BG E. D. Peixotto, CE, and COL G. H. Hilt, CE. Technical Director was Mr. F. R. Brown.

CONTENTS

LIST OF TABLES

U.S. ARMY ENGINEER
WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS
P.O. BOX 631
VICKSBURG, MISSISSIPPI 39180

FINAL PROJECT REPORT

STATE Illinois

CONTRACT NO. DACW39-73-C-0015

PROJECT TITLE Study of Importance of Backwater Chutes to a Riverine Fishery

PERIOD COVERED September 1, 1972 - May 31, 1973

PREPARED BY Harold L. Schramm, Jr., Research Assistant under the supervision of Dr. William M. Lewis, Director Fisheries Research Laboratory, Southern Illinois University Carbondale, Illinois 62901

APPROVED BY William M. Lewis DATE

APPROVED BY Roy C. Heidinger DATE

INTRODUCTION

This is a review of the literature basic to the preparation of an environmental impact statement in connection with proposed changes in the channel of the Mississippi River between St. Louis, Missouri, and Cairo, Illinois.

Emphasis is on the possible effects on the side channels of altering the river channel. An attempt has been made to condense and organize the available literature in such a way that the importance of the side channels is apparent. Basically, the approach is to describe the habitats which occur in the above mentioned section of the Mississippi River, to discuss the conditions of existence most favorable and least favorable to the biota, and, on this basis, to conclude the effects that these changes might have on the biota, especially the fishes.

To determine the environmental impact of the loss of backwater areas, a comprehensive review of the literature was conducted by the author from 1 September 1972 to 31 May 1973. Approximately 600 hours were spent retrieving and reviewing literature in two general areas: literature pertaining to the physical, chemical, and biotic factors of larger rivers, and literature pertaining to the biology of the fishes recorded as present in the section of the Mississippi River of concern. One hundred and eighty hours were spent preparing the report.

The limited data that were available has been tabulated. The conclusions of this report are based on these tables, and on the conclusions and information supplied by the authors whose works were employed.

Initial access to the pertinent literature relied on

several specific bibliographies: Mechanic (1971), Sport Fisheries Abstracts; Fishery Publication Index, 1920 - 1954; U.S. Government Publications (1972); MacDonald (1921); Biological Abstracts; and UMRCC (1967). Additionally, the bibliographies of each article used were consulted for references.

The literature reviewed is organized into three parts: classification of the habitats; comparison of habitats, including physical and chemical conditions, and the biota of rivers, excluding fish; and the ecology of the fishes. Two discussions of factor interactions are presented. The first describes the interactions among the biota, excluding the fish, and the interactions between the biotic elements, excluding the fish, and the physicochemical factors. The second discussion of factor interactions pertains to the fish and other biotic elements. These discussions are designed to serve as statements of the impact of the proposed engineering works on the river environment and the river fishery.

CLASSIFICATION OF HABITATS

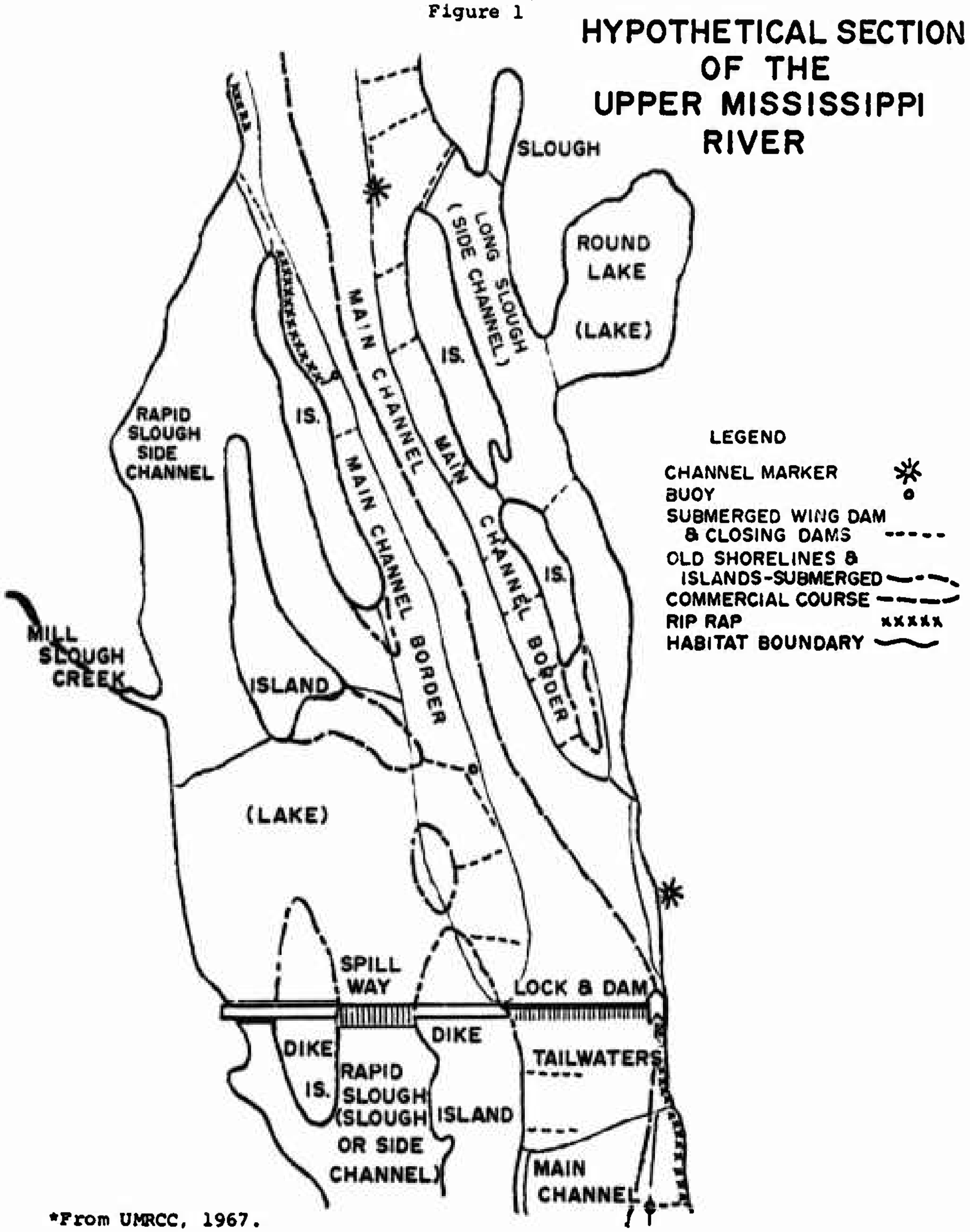
The Fish Technical Section of the Upper Mississippi River Conservation Committee made a recent study of river habitats to standardize nomenclature and description. The habitat types are: Main Channel, Main Channel Border, Tail Waters, River Lakes and Ponds, Side Channels, and Sloughs (UMRCC, 1967).

These habitats are pictured in Figure 1, and will be briefly described.

Main channel includes only the portion of the river in which large commercial craft can operate. It is defined by combinations of contraction works (wing dams and riprap), river banks, islands, and buoys and other markers. It has a minimum depth of nine feet and a minimum width of 400 feet. A current always exists, varying in velocity with water stages. The bottom type is mainly a function of current: sand, silt over sand, and occasional patches of gravel are the main types. Most of the main channel is subject to scouring action during periods of rapid water flow and by passage of tow boats in shallower stretches. No rooted aquatic vegetation is present.

The main channel border is the zone between the nine-foot channel and the main river bank, islands, or submerged definitions of the old main river channel. It includes all areas in which wing dams occur along the main channel. Buoys often mark the channel edge of this zone. Where the main channel is defined only by the bank, a narrow border still occurs, and often the banks have riprap and fair to good fish habitat. Dredge spoil has been placed in some sections of this zone, sometimes covering the wing dams. The bottom is sand or silt. Little or no rooted aquatic vegetation is present. This zone provides some of the better fishing along the river at certain times of the year.

Figure 1*



*From UMRCC, 1967.

Tail waters include the main channel, main channel border, and other areas immediately below dams which are affected by water passing through dams and locks.

Side channels include all departures from the main channel in which there is current during normal river stages. The gradations in this category are wide, ranging from fast flowing watercourses with high banks to sluggish streams winding through marshy areas. The banks are usually unprotected; undercut or eroded banks are common along side channels near their departure from the main channel. Bottom type varies from sand to silt. There is no rooted vegetation in areas of swifter current, but vegetation is common in the shallower areas which have silt bottoms and moderate to slight current. Other terms that have been used for this habitat are sloughs, running sloughs, chutes, cuts, cut-offs, and canals.

River lakes and ponds is a general category for the following lake types described by Hutchinson (1957):

Type 49 - lakes formed by fluviatile dams,
Type 55 - oxbows or isolated loops of meanders,
Type 56 - lakes formed in depressions on floodplains,
Type 57 - lakes formed between natural levee and scarp, and
Type 73 - lakes formed by man-made dams.

Only those lakes having some connection with the river during normal water stage are usually considered. River lakes and ponds may or may not have a current, depending on location.

Bottoms are mostly mud and silt, often two, or more, feet thick. Many of these waters have an abundance of rooted vegetation, both submerged and emergent. They are often surrounded by marsh land. The term backwater has often been used to name this habitat. Using this present classification system, backwaters and bayous are considered either river lakes and ponds or sloughs (see following habitat type description) depending on specific characteristics.

Sloughs include all the remaining aquatic habitat in the river. Certain sloughs border on the "lake or pond" category; other sloughs approach the characteristics of "side channels". Sloughs may be former side channels that have been cut off or have only intermittent flow. They may be relatively narrow branches or off-shoots of other bodies of water. They are characterized by no current at normal water stage, muck bottoms, and an abundance of submerged and emergent aquatic vegetation. Another term for slough is "dead slough".

The present study concerns the environmental impact of dikes (wing dams) on backwater chutes between St. Louis, Missouri, and Cairo, Illinois. These backwater chutes can, in general, be called side channels, following the UMRCC habitat classification scheme.

A full treatment of the environmental impact of changes in side channels necessitates the study of additional habitat

types. The conditions of existence in sloughs and river lakes and ponds can be dependent on the hydrologic conditions of the side channels. Also, the side channel itself can exhibit a diversity of environmental conditions, e.g. bottom type, depth, channel morphometry, and velocity of flow. Because of the potential interdependence and similarity, the complex of habitats classified as side channels, river lakes and ponds, and sloughs will be designated "extra-channel" areas.

Although specific predictions about the effect of wing dams on the hydrologic conditions of the side channels cannot be made without looking at the individual side channel, three general changes are possible: increased volume of flow and decreased volume of flow in the side channel, and closing the side channels from the main channel. The literature review has been directed towards gaining information about side channels and associated habitats, and information about systems which would be similar to the systems resulting from the possible changes of the side channels. The importance of side channels has been determined by comparing the physical, chemical, and biotic conditions of main channels and main channel borders with those conditions of side channels, river lakes and ponds, and sloughs. From knowledge of the effects of changes in the extra-channel habitats, and the importance of side channels and associated habitats, the environmental impact of wing dams

which would close the side channels was determined.

COMPARISON OF HABITATS

It is necessary to compare habitats to determine the benefit of extra-channel habitats to the Mississippi River fishery. A full understanding of the fishery entails a knowledge of physical and chemical limnological factors, phytoplankton, zooplankton, benthos, macrophytic vegetation, and fish. We must investigate the food chains and the environmental factors which affect the constituents and levels of the food chain.

Tables 1 through 9 have been prepared from the available literature on river systems. Emphasis has been placed on slow flowing North American rivers with habitat diversity similar to that found in the Mississippi River from St. Louis to Cairo. Several conclusions can be drawn from these tables.

Physical and chemical factors

Among the physical factors such as current, bottom type, turbidity, water level fluctuation, alkalinity, nutrients, and oxygen concentration, several correlations are apparent. Current has been considered a predominating factor in lotic systems. Although bottom type and turbidity are affected by local geological differences in different areas, Table 1 indicates that faster current areas have a bottom of coarse, hard materials (rock, gravel, bedrock) and higher turbidity (e.g. the Missouri River, Berner, 1951). Slower current areas

have a bottom of soft, fine materials (mud, silt, and fine sand) and lower turbidity. These relationships become more apparent when the extra-channel habitats are compared with the main channel. It can be seen that current varies from reduced to slack in these areas, bottom types are primarily soft mud, silt, sand, often with a top layer of organic matter. Butcher (1927) has shown a gradation of bottom types with current velocity and fall per mile, and stated that current determined bottom type (Butcher, 1933).

Current has been considered the primary factor affecting flowing water systems by its effect on turbidity and sediment load (Lakshminaryana, 1965; Jackson and Starrett, 1959; Dill, 1944; Reinhard, 1931; and Briggs, 1948). Turbidity is greatly reduced with reduced velocity. Morris, et al. (1968) found silt turbidity of the channel to be twice the value of a slack water chute in a study of the Missouri River. Stuart (1960) has shown a correlation between increased current, lack of substrate diversity, and increased turbidity as a result of dredging works. Ellis (1936) considered silt and turbidity to be the major factor that influences the biota in lotic systems due to its reduction of low wavelength light, the retention of organic matter and inorganic nutrients, which can disrupt the chemical cycles, and the covering of organic matter on the substrate, which will retard oxidation and

change the water chemistry. He stated that anything that affects the current will affect silt turbidity. Edwards (1969) adds that siltation can change or eliminate habitats.

Although no direct data are available to demonstrate the water fluctuations associated with different habitat types, Stuart (1960) has reported increased fluctuations in water level following channelization. Stuart supported several reasons for the increased fluctuations of level. The straightened watercourse and smoothed, homogeneous bed result in a loss of bed friction and an increase in effective slope. This increases the velocity of flow, and, thus, allows a given amount of water to pass downstream faster. The longitudinal and lateral asymmetry and roughness of a diverse substratum would hinder the flow and slow the rate of fluctuations. A second reason is the loss of areas of water storage which would act as reservoirs. These areas would augment the volume of discharge of the river during periods of low water, and, therefore, tend to stabilize the flow.

A study of correlations between habitat types and chemical factors (Tables 2 and 3) indicates that most differences in chemical factors are due, not to the influence of habitat types within the river itself, but rather are due to the geographic and geologic area through which the river flows (Griffiths, 1923). Alkalinity will be higher in calcareous

regions. The quantity of inorganic and organic nutrients can be greatly increased by domestic and industrial pollution (e.g. the upper Mississippi River, Reinhard, 1931).

Oxygen values have been reported as the range of values reported by various authors. This takes into consideration the seasonal differences in dissolved oxygen due to temperature and photosynthesis and respiration. The dissolved oxygen values are, in general, lower in the main channel than the extra-channel areas. Since, in running water systems, dissolved gases are usually more or less in equilibrium with the atmosphere (Hynes, 1970), this observation appears aberrant, but aeration by current is not the only factor which affects dissolved oxygen. Washed in organic matter and the decrease of photosynthesis caused by turbidity can lower oxygen concentrations (Dorris, et al., 1963; Gessner, 1961). This is further discussed in the section on phytoplankton. Also organic matter will tend to remain in circulation in the water column instead of settling to the bottom, and, therefore, increase the oxygen demand. Under conditions of complete stagnation, high organic content can lower oxygen concentrations (Kajak, 1968). Wave action plays a role in aeration of lake-like habitats (Boruff, 1930).

The importance of physical and chemical factors, and the interaction of the factors, are discussed more fully in the

sections dealing with the various groups of the biota.

Phytoplankton:

The phytoplankton forms the base of aquatic food chains. Although not the exclusive source of nutrition for the consumers in the food web, their role in primary production is essential to the system (Hynes, 1970). Forbes (1928) outlines the flow of energy from algae and protozoa to zooplankton, to macro-invertebrates, and to small fish. Table 4 shows the taxa, and their abundance, in the different habitat types found in the Mississippi River, St. Louis, Missouri, to Cairo, Illinois. Interpretation of Table 4 is made difficult by the available data which was used to compile the table. Most studies on river phytoplankton have been concerned with the taxa present, with the effect of pollution on the biota, the seasonal periodicity of the biota, or the ecology of the organisms. Only several studies dealt with the biotic differences between habitat types, and of those that did, accurate habitat descriptions are often wanting. For the purpose of this paper, the results of various authors have been categorized into the main habitat classifications used in this paper as accurately as possible. An additional problem involved in using this data to draw valid conclusions is that few rivers have the habitat diversity of the Mississippi River, and, therefore, equal amounts of information are not available for all habitat

types. Table 4 shows that the amount of research done on main channel habitats exceeds that of the extra-channel habitats. This prevents the application of diversity indices to the various habitat types. The first conclusion that can be drawn from Table 4 is the need for research pertaining to biotic differences between the different habitat types within the same river system.

Study of Tables 4 and 5 indicates that Chrysophyta dominate in the habitats under the influence of the current. Cyanophyta and Euglenophyta show reduced abundance and diversity. Comparison of the channel border habitat with the main channel shows that the flora is reduced in diversity. The Chlorophyta are slightly reduced in abundance and the Chrysophyta show an increase in abundance. Cyanophyta show little change, except a filamentous form (Lyngbya) shows a great increase in abundance. The increase in Lyngbya may be due to the decreased current, and possibly the difference in substratum type. The data for Lakes Pepin and Keokuk (Galtsoff, 1924) are useful in indicating the increase in abundance as the current slows. This is especially apparent when the results from upper Lake Keokuk are compared with lower Lake Keokuk. The increased abundance pertains to the Chrysophyta, Chlorophyta, and Cyanophyta. In reduced current and slack current habitats, the chlorophytans are dominant and the cyanophytans

increase in abundance. Fritsch (1903) found green algae decreased in diversity but increased in abundance in backwaters. Fritsch (1902) found that diatoms were the dominant plankters in the backwater areas.

Typical communities have been derived from Table 4. (See Table 5.) It can be seen that the community of dominant organisms in the main channel is made up of the same organisms found in the extra-channel habitats except for the filamentous green algae typical to the river lakes and ponds (*Zygnema*, *Ulothrix*, *Spirogyra*, *Chaetophora*, and *Cladophora*) and several cyanophytans (*Cathrocystis*, *Aphanizomenon*, and *Oscillatoria*) typical of standing water. The information in Table 5 indicates that floristic differences in different habitats are primarily due to differences in abundance and not due to changes in species composition.

The limited data on phytoplankton production (Galtsoff, 1924) indicated that production is highest in standing water, lowest in the channel border, and intermediate in the main channel. Data were not available for side channels and river lakes and ponds, but Fritsch (1903) found a richer phytoplankton in the backwaters of the River Thames than in the channel itself.

The source of phytoplankton varies in different river systems. Fritsch (1902, 1903), Zacharias (1898), Kofoid (1908),

Berner (1951), Purdy (1930), and Schmidle (1898) stated that algae are derived from tributary areas (small streams, backwaters, ponds, bays, etc.) above sampling areas. Hartman and Himes (1961) found that impoundments affect phytoplankton for a considerable distance downstream. In larger, deeper rivers phytoplankton are derived from pools, backwaters, and the littoral zone, but the riverbed is the most important source (Butcher, 1932). Blum (1956) found benthic plankton to greatly exceed euplankton. Macrophytic vegetation has been shown to be an additional source of plankton (Fritsch, 1905; Blum, 1960; and Rice, 1938). Galtsoff (1924) used the term "polymixic" to describe the origin of river plankton; i.e. plankton is supplied from the littoral and benthic areas of the river, and from adjacent lakes and ponds of the river basin.

Several physicochemical factors affect the abundance and diversity of phytoplankton. Current is a factor of major importance. Schroeder (1899) stated that plankton is inversely proportional to the slope of the bed. Although some benthic algae are benefited by increased current, in general phytoplankton showed an increase in production in the following order: rapid streams, slow streams, quiet portions of streams (Blum, 1956). Eddy (1934) stated that velocity determined the point in the stream at which plankton development begins.

This is in agreement with Allen (1920): current velocity above a certain level is inimical to plankton algae. High current velocity can cause mechanical destruction of the algae (Hartman and Himes, 1961; Hynes, 1970; Reinhard, 1931; and Galtsoff, 1924). Because of the effect of current on phytoplankton, productivity is different in different areas of the river (Galtsoff, 1924). The following authors are supportive of the reductive effect of current on phytoplankton abundance: Hutchinson (1939), Starrett and Patrick (1952), Coker (1929), Berner (1951), Lakshminaryana (1965), Brook (1954), Brook and Rzoska (1954), and Swale (1969). It has been shown that some current is beneficial to phytoplankton due to a physiological enrichment; i.e. the "diffusion shell" of nutrient poor water surrounding an organism is reduced by current (Whitford, 1960). This can result in increased production (Ruttner, 1963).

The composition of the phytoplankton changes with current. Butcher (1932) found green and blue-green algae to increase in larger rivers. This is in agreement with the increase of these two groups in backwater areas (Fritsch, 1903). Swale (1969) attributed the scarcity of blue-green algae to the absence of areas with slow flow.

Mechanical destruction is one of the direct ways current can affect phytoplankton. All forms are reduced (Hartman and Himes, 1961), but because diatoms are the most tolerant of

current, the composition of the phytoplankton is changed (Hynes, 1970).

Water level fluctuations can cause changes in the phytoplankton. Changes in water level fluctuations are often associated with current, the effects of which have been discussed, but are also associated with nutrient replacement. For this reason, plankton increased following flood conditions (Blum, 1956). Coker (1929) found plankton to increase in inundated areas during floods; this could be due to nutrient enrichment. Plankton has been shown to decrease during flood stages and/or increase under stable conditions by the following authors: Lakshminaryana (1965), Hutchinson (1939), Galtsoff (1924), Kofoid (1903), and Rice (1938).

Turbidity can be a controlling factor of phytoplankton occurrence. The effect of turbidity on nutrients and light penetration, and the relationship with current has been mentioned in the section on physical factors. High turbidity can so effectively reduce light penetration that phytoplankton growth is prevented (Blum, 1956). The inhibitory effect of turbidity on phytoplankton by light reduction has been shown by Lakshminaryana (1965), Berner (1951), and Edwards (1969). Turbidity becomes especially important when the algae of the river bed are considered. Turbidity also causes a settling-out of the plankton (Starrett and Patrick, 1952; and Dill,

1944), or mechanical destruction of the cells (Hynes, 1970).

Reduced current, turbidity, and water level fluctuations are the most favorable conditions of existence for phytoplankton and periphyton production. These physical conditions are associated with the extra-channel habitats.

Zooplankton

The zooplankton is essential to the aquatic food web. Although some larger consumers are herbivorous, phytoplanktophagic, or detritophagic, the zooplankton serve as a link between the primary producers and the higher level consumers -- macroinvertebrates and small fishes.

Table 6 is a list of the zooplankton recorded from various river habitat types and their abundance. The problems associated with interpretation of Table 6 are the same as discussed for Table 3 (see section on phytoplankton), but several conclusions can be drawn.

Rotifera dominate in the main channel, both in number and diversity. (See Tables 6 and 7). Rotifers decline in occurrence in the channel borders, where the fauna is quite limited, although Rotifer remains abundant. Rotifers also decline in sloughs. The rotifer fauna of river lakes and ponds exceeds that of the main channel in diversity, but the results indicate that abundance is lower.

Cladocera are also quite diverse in the main channel and

river lakes and ponds, relative to the other habitat types. The greatest abundance occurs in river lakes and ponds.

Copepods are restricted in diversity in the main channel and channel border, and show increased diversity in river lakes and pond habitats. The abundance is lowest in sloughs. The maximum abundance was noted in a bank area of Lake Pepin ($125,000/m^3$). A maximum abundance of $44,000/m^3$ was recorded for the channel border habitat (Galtsoff, 1924).

The protozoans were found to show greatest diversity in river lakes and ponds and the main channel. References are insufficient for the other habitats to allow adequate comparison.

A more precise indication of the effect of reduced current habitats on zooplankton can be seen by focusing on several studies. The dominant genera of rotifers increased in abundance in the slack current section of the Hocking River (Hutchinson, 1939) and the Ohio River (Purdy, 1923). Cladocera and Copepoda showed no change with decreasing current. The reduction of current in Lakes Pepin and Keokuk had little effect on the zooplankters.

A study of typical communities (Table 8) indicates differences between the zooplankton in different habitat types. The rotifers, cladocerans, and copepods of the main channel are also found in the river lakes and ponds and sloughs, but several genera are dominant in the latter two habitats which are only

of occasional occurrence in the main channel (*Asplanchna*, *Lecane*, *Euchlanis*, *Triarthra*, *Noteus*, *Rattulus*, *Leptodora*, *Sida*, *Moina*, and *Simocephalus*).

Generalizations available in the literature indicate that the abundance and diversity of zooplankton are affected by environmental factors very similar to those factors affecting the phytoplankton.

Current exerts a marked effect on zooplankton. Low zooplankton concentrations were associated with a high stream gradient (Starrett and Patrick, 1952; and Schroeder, 1899). Zooplankton have been found to increase in abundance (Cushing, 1964; Ellis, 1931; Galtsoff, 1924; Kofoid, 1903; Swale, 1969; Hutchinson, 1939; Eddy, 1934; and Brook and Rzoska, 1954) and in diversity in slack current areas. Jones (1941) and Eddy (1934) found the increased abundance and diversity in slack current areas was due to the addition of lenitic species. The entomostraca showed the greatest increases (Coker, 1929; Brook and Rzoska, 1954), although Galtsoff (1924) found rotifers also increased. Galtsoff (1924) found zooplankton to increase near bank areas but found a decreased abundance behind pile dikes. This indicates that current is not the only limiting factor.

Rapid water level fluctuations, in general, tend to reduce the populations, and greatest abundance is associated with

stable conditions (Galtsoff, 1924; and Hutchinson, 1939). Water level fluctuations, excluding the inimical association with current, can be beneficial. An increase in shallow-water areas increased total plankton production (Forbes and Richardson, 1913). It can be seen that inundated areas increase during floods.

Turbidity is deleterious to zooplankton. Silt can interfere with feeding and respiration (Chutter, 1969). A general decrease in zooplankton caused by silt turbidity was found by Eddy (1934) and Berner (1951).

The source of supply of river zooplankton is primarily quiet water areas (Berner, 1951; Ellis, 1931a; Coker, 1929; Reinhard, 1931; Forbes and Richardson, 1913; Chandler, 1937; Schmidle, 1898; Kofoid, 1908; and Galtsoff, 1924). Macrophytic vegetation contributes some zooplankton to the main channel (Monakov, 1969). This enrichment lasts up to five miles below the source area (Hartman and Himes, 1961). Zooplankton are also affected by mechanical destruction in the current (Reinhard, 1931; and Hynes, 1970).

<u>Benthos</u>:

The benthos is an integral component of the river food web. Many of the larger consumers in the river are, at least in part, benthophagic. Table 8 is a compilation of benthos found by various researchers categorized into major habitat

types. Problems of interpretation of this data are as discussed for Table 3 in the section which discussed phytoplankton, except the available literature on benthos shows as even greater preponderance of data about main channel fauna.

To simplify the interpretation of Table 8, only those organisms frequently utilized for food by fish have been compared. The data indicates no striking differences between the different habitats for the following groups: Diptera, Ephemeroptera, Trichoptera, Oligochaeta, Gastropoda, and Pelycepoda.

A more precise understanding of faunistic differences between habitat types can be seen by a detailed study of the work of several authors. Morris, et al. (1968), studying the effect of channelization on the Missouri River (see Table 8), found that channelization resulted in the elimination of gradually sloping bank areas and chutes (side channels). Current velocity, fluctuations in water level, and mud bank area increased. The oligochaetes increased in abundance with channelization. This increase was due to the increase in mud bank area. Ephemeroptera and Trichoptera decreased in abundance. The standing crops were highest in the chutes and mud bank areas of both the channelized and unchannelized sections. Mikulski (1961) found the greatest benthic density to occur in stagnant areas and found decreased density in the channel borders, and a further decrease in the main channel. Berner

(1951) found a higher standing crop in the mud banks of the channel border compared to the main channel. The production of slack current areas (sloughs, lakes, bays, cut-off bends) exceeded the poor production of the main channel (Dill, 1944).

The above studies and the interpretation of Table 8 indicate the importance of current in benthic production. Benthos showed increased abundance with reduced current velocity. The general reductive effect on benthic diversity with increased current has been found by Briggs (1948), Richardson (1921), Berner (1951),Mikulski (1961), and Berg (1948).

Substrate, turbidity, water fluctuations, depth, and dissolved oxygen are also major factors which affect benthic abundance. Richardson (1921) found the richest benthos in sluggish sections of the Illinois River with heavy sedimentation. Lake production in open water was less than in the river, but the benthos of the shoreline vegetation approached the abundance in the river. Mikulski (1961) observed greater density on "transit silts" (silt deposited in narrow bands on the channel floor) than adjacent sand habitats. Lyman (1943) and Forbes (1928) found mud bottoms were the most productive areas. Barnickol and Starrett (1951) point out the lack of favorable substrates and substrate diversity in sections of the Mississippi River where extra-channel areas are minimized. This results in reduced quantity and diversity of benthos.

Macrophytic vegetation acts as a substrate for benthos, and, indirectly, affects benthos by modifying the bottom. The increased abundance associated with macrophytic vegetation has been shown by Monakov (1968), Moore (1920), Berg (1948), Dill (1944), and Richardson (1921). All of the above works indicate that the substrate affects benthic production.

Fluctuating water levels are generally detrimental to benthic fauna. The occurrence of benthos is affected by uneven flow (Spence and Hynes, 1971). Production decreased under unstable conditions (Berner, 1951; Mikulski, 1961; and Briggs, 1948). Flooding caused organisms to be washed away or carried downstream (Richardson, 1928; Sprules, 1947).

Silt turbidity can exert a severe effect on benthic organisms. Siltation is indirectly deleterious to the bottom dwellers by filling in interstices (Chutter, 1969; Ellis, 1936) and changing and eliminating habitats (Harrison, et al., 1963; Edwards, 1969; Ellis, 1931b). Silt directly affects the benthos by covering the organisms themselves (Ellis, 1931a), and by affecting feeding (Chutter, 1969), and respiration (Paloumpis and Starrett, 1960). Siltation was shown to cause a change in fauna to types less desirable as forage for fish (Eustis and Hillen, 1954). Decreased benthic productivity due to silt turbidity was observed by Berner (1951), Dill (1944), Morris, et al. (1968), Sumner and Smith (1939), and

Taft and Shapavalov (1938). Certain degrees of siltation can be beneficial, as has already been cited in Richardson's (1921) and Mikulski's (1961) work. (See discussion of the effect of the substrate.) In quiet water areas, nutrients and organic debris settle, yielding an increased richness of the substrate for the benthos (Dill, 1944; Lambou, 1959).

Depth has been found to affect the occurrence and abundance of benthos. Greatest production was observed in shallower waters (Ludwig, 1932; Richardson, 1921; Needham, 1934).

Very low oxygen levels, or oxygen depletion, are inimical to almost all aerobic heterotrophs. Various concentrations of oxygen can determine the composition of the benthic organisms. Wiebe (1927) found that low dissolved oxygen concentrations severely affected clean water benthos.

We can now see that the conditions found in extra-channel areas, i.e., reduced current, reduced turbidity, reduced water fluctuations, shallower water, soft substrate, increased concentrations of dissolved oxygen, are the most favorable conditions for the development of benthic communities. The conditions found in the main channel have a reductive effect on the benthos. Therefore, habitats with the general characteristics of extra-channel areas are needed.

Macrophytic vegetation

The macrophytic vegetation of rivers must be considered

when concerned with the fishery. Macrophytes are larger types of flora, visible to the observer without special equipment; macroscopic filamentous algae are considered macrophytes. Macrophytes are used as a food supply by some fish (Moore, 1920). Although macrophytes play a minor role in the food web directly, they are important modifiers of the habitat, producing oxygen, substrate for algae (Butcher, 1933) and various micro- and macroinvertebrates (Berg, 1948; Jones, 1949), and facilitating nutrient circulation. Table 9 illustrates the increase in vegetation in slow flowing areas and in silted areas, compared to fast flowing, hard substrate streams. This is supported by Butcher (1933). Macrophytic vegetation can also be inhibited by silt turbidity (Butcher, 1927; Edwards, 1969), which will reduce light penetration, and, subsequently, photosynthesis (Cordone and Kelley, 1961). Fluctuating water levels can subject the plants to dessication or submerge them to such a depth that insufficient light is available for photosynthesis. It has been shown that fast currents, hard bottoms, high turbidities, and widely fluctuating water levels are characteristics of the main channel areas. Therefore, main channel areas are inimical to macrophytic vegetation. These inimical conditions are, although they may still be present, reduced in extra-channel areas. Westlake (1966) reported that some current caused increased productivity of <u>Ranunculus fluitans</u>, compared

to static water. Therefore, chutes, sloughs, and river lakes and ponds provide more favorable conditions of existence for macrophytic vegetation.

Interaction of biotic elements and physicochemical factors

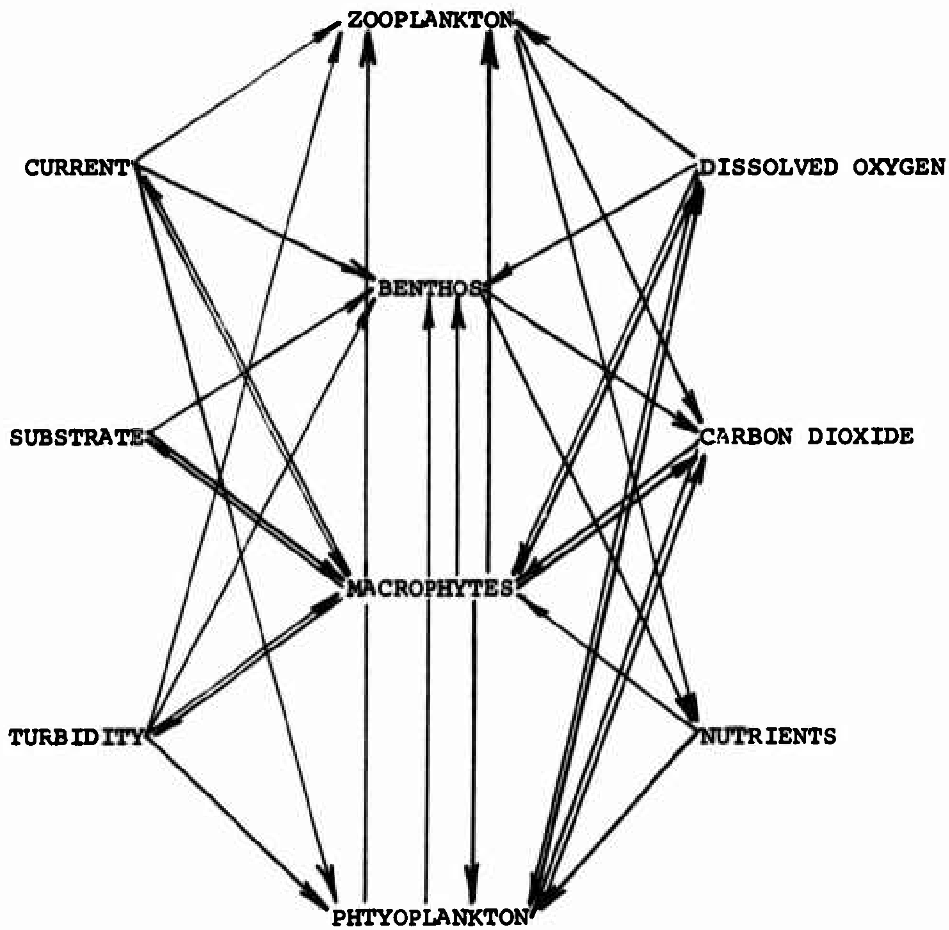
Before proceeding to the presentation of information about the fishes found in the section of the Mississippi River, St. Louis to Cairo, and a discussion of the importance of various habitat types, physical and chemical conditions, and food supplies, it may be beneficial to recapitulate the variables that have been indicated as important to the fishery, and to more fully discuss the factor interactions of these important parameters.

It has been shown that increased current and turbidity are detrimental to the algae, zooplankton, benthos, and rooted aquatic vegetation. Hard, homogeneous substrates are also inimical to the production of benthos and macrophytic vegetation. Dissolved oxygen can limit the fauna, micrometazoan and macrometazoan. Dissolved oxygen, carbon dioxide, and various nutrients can limit the growth of the microscopic and macroscopic flora. High current velocities, high silt turbidities, and a hard substrate are typical characteristics of the main channel areas of large rivers. Dissolved oxygen is frequently lower in main channel habitats, due to reduced photosynthesis (primarily a function of increased current, turbidity, and depth) and

recirculation of decomposable matter. Nutrients can be limiting in the main channel, due to physical association with silt particles and dilution effects during flooding. From the direct effect of these physical and chemical factors on the flora and fauna, it can be seen that main-channel habitats are inimical to the development of the biota. The extra-channel habitats provide more favorable conditions of existence for the biota, and will hence increase the biota.

To approach a full understanding of the conditions of existence for the flora and fauna which are directly, or indirectly, important to the fishery, we must also consider the interactions among the biota and the interaction of the biotic factors and the physicochemical factors. (See Figure 2.) The zooplankton and benthos utilize algae. Therefore, the algae affect the zooplankton and benthic productivity. The zooplankton and benthos facilitate nutrient cycling by consumption of the algae and excretion of readily decomposed waste products. The oxygen-carbon dioxide cycle is maintained by the algae and macrophytes, suppliers of much oxygen, and the zooplankton and benthos, the suppliers of much of the carbon dioxide. In addition to the production of oxygen, their role in nutrient cycling, the provision of substrates, and as a food supply (Pond, 1905; Hotchkiss, 1941) aquatic macrophytes can be significant modifiers of the environment by their effect on reducing the current

Figure 2
The interaction of physical, chemical, and biotic factors



Legend:

CURRENT ⟶ MACROPHYTES indicates current is affected by macrophytes

MACROPHYTES ⟶ CURRENT indicates macrophytes are affected by current

PHYTOPLANKTON ⟶ ZOOPLANKTON indicates zooplankton are supported by phytoplankton

and turbidity (Butcher, 1933). An additional ramification of rooted aquatic plants is to facilitate the buildup of a soft, often highly organic, due to the death and decomposition of plant parts, stable substrate in areas of heavy stands of phanaerogams (Butcher, 1933; Edwards, 1969). Therefore establishment of rooted aquatic vegetation in areas with high currents and turbidities and firm substrate can result in a reduction of these inimical factors. As conditions of existence for macrophytes improve, the abundance of the macrophytes will increase, and thereby, the benefits imparted by these plants to other members of the food web will subsequently increase. Of course the beneficial effect will be maximized in extra-channel areas where conditions are more favorable for the development of rooted vegetation; i.e., the habitat which favors increased macrophytic vegetation will receive the greatest degree of benefit provided by the vegetation.

It should now be obvious that the conditions of existence associated with extra-channel habitat types are more favorable for the production of organisms related, directly or indirectly, to the food of fishes. This is supported by the work of Dill (1944), Eggleton (1939), Richardson (1921), and Stuart (1960). The favorability of these conditions of existence is determined primarily by physicochemical conditions, and when the conditions of existence become increasingly suitable for the biota,

biotic factors and factor interaction can additionally increase the favorability of the habitat.

An indirect benefit of the favorable conditions of existence for development of the biota in extra-channel areas is self-purification of organically polluted water.

The high biological oxygen demand necessitated by the decomposition of organic compounds is best met by the oxygen production of the primary producers (Boruff, 1930; Marsson, 1911; Richardson, 1928; Purdy, 1930). The presence of adequate oxygen provides suitable conditions for aerobic decomposition (Marsson, 1911) and prevents oxygen depletion that would be detrimental to all heterotrophs.

Organic pollutants are directly consumed by some organisms. Diatoms, fungi, protozoans, rotifers, crustaceans and a diversity of benthic invertebrates (Marsson, 1911; Purdy, 1923, 1930) are able to directly reduce the quantity of dissolved and particulate organic matter in the water.

The overall effect of self-purification is the change from a polluted habitat to a habitat with conditions favorable for clean water organisms (Wiebe, 1927; Purdy, 1923; Richardson, 1928), as a source of clean dilution water for the river system (Bardach, 1964; Boruff, 1930), and as a source of usable nutrients for the primary producers (Marsson, 1911; Purdy, 1923).

The most favorable conditions of existence for the organisms involved in self-purification have been shown to occur in extra-channel areas. This is supported by Richardson (1928) and Wiebe (1927).

Therefore, because the extra-channel habitats provide the most favorable area for the production of organisms intricately involved in the food webs in which fish are the final consumers, and in improving the quality of water in which all organisms live, destruction of these habitats, or any mainpulation which hinders access to these habitats, may result in some degree of reduction of fish production to the river fishery. Stuart (1960) supports the creation of slack current habitats to improve the physical conditions and benefit the biota.

ECOLOGY OF THE FISHES

The following pages and Table 10 are included to describe, in detail, the biology of the fishes recorded as present in the ongoing study. Lists of the fishes known to be present in the Mississippi River, St. Louis, Missouri, to Cairo, Illinois, were supplied by S. Lewis and D. Ragland. From the information gathered about these fish, better estimates of the importance of the physical, chemical, and biotic factors can be determined, and the impact of the loss of the extra-channel areas concluded.

The following descriptions of the biology of fishes are

based on information in the following references: Calhoun (1966), Carlander (1969), Barnickol and Starrett (1951), Gerking (1945), Swingle (1956), UMRCC (1967), Forbes (1888), Forbes and Richardson (1920), Coker (1930), Fish (1932), Luce (1933), Hankinson (1919), and Trautman (1933). Specific references are cited where appropriate.

The fishes present

Amia calva

The bowfin, dogfish, grindle, spot-tail or mudfish is of general occurrence in rivers and lakes but is most abundant in sloughs adjacent to the Mississippi River. The adult bowfin is exclusively carnivorous; its diet is comprised of varying percentages of fish, frogs, crayfish, molluscs and occasionally leeches. Although the bowfin in prepared for food in certain areas, it is generally not sought commercially. The bowfin is extremely gamy, but few fishermen actively seek this fish. Due to minimal fishing pressure, reduced vulnerability due to large size, and tenacity this fish often becomes abundant. The bowfin's abundance and predatory nature have led fishermen and some biologists to regard it as a nuisance species.

Spawning occurs in May to June in southern Illinois and is preceded by movement into shallow, densely vegetated areas where the smaller male clears vetetation away from plant roots or builds a form of nest of the vegetation. Nests are

frequently colonial. The large female deposits 2000 to 5000 eggs in the nest. The eggs are adhesive and adhere to the roots and rubble in the nest. Eddy and Surber (1943) have reported 64,000 eggs/ovary in a 21-inch fish. Maturity is reached in 4 years. The eggs hatch in 8 to 14 days and leave the nest at 9 days depending on the temperature. The young remain in a dense school guarded by the male until 4 inches long.

The bowfin has a vascularized swim bladder. This allows the fish to breathe air at the surface, and thereby serves as an adaptation to life in stagnant, low oxygenated water often found in swamps and shallow lakes.

Lepisosteus osseus

The northern longnose gar, billy gar, or billfish is widely distributed in lakes and large rivers and is most abundant in stagnant waters. The longnose gar is not recognized as a fish of commercial or sport importance, but when hooked this fish puts up a good fight.

Reproduction occurs May to June. Spawning occurs in shallow water over weed, where a single female, usually accompanied by several males, will deposit up to 77,000 adhesive eggs. These eggs are poisonous and hatch in 3 to 9 days depending on temperature. The young remain in shallow, vegetated water and grow rapidly, reaching a mean total length of

15 to 20 cm in the first year. Young have been reported to become piscivorous at 5 cm (Carlander, 1969). Maturity is reached at 4 years in males and 6 years in females.

The longnose gar is almost exclusively piscivorous, frequently feeding on valuable game fish. Coker (1930) states that the longnose gar is commonly known as a nuisance, but this fish's harmful effect on game fish is by competition with game fish for food. The ability to breathe air, due to a vascularized swim bladder, the tough, armor-like skin, the rapid growth to a large size, high fecundity, and lack of fishing pressure frequently result in great abundance and can make this fish a severe nuisance.

Lepisosteus platostomus

The shortnose gar, short bill, stub-nose gar, or billy gar is usually the most abundant gar in rivers and lakes and prefers open waters. Like the longnose gar, this fish has little or no commercial and sport fishing importance.

The life history and ecology of *L. platostomus* is very similar to that of *L. osseus*. Reproduction differs from the longnose gar in that spawning often occurs over inundated land and the eggs are able to withstand dessication (Forbes and Richardson, 1920), and spawning period extends into the summer.

Due to the lack of fishery importance and the life history and ecology similar to the longnose gar, the shortnose gar is

a serious nuisance to sport and commercial fisheries.

Hiodon alosoides

The goldeye is widely distributed in some lakes and larger rivers but is common in only some Mississippi River oxbow lakes. Little specific information is available for this fish and the next fish discussed, *H. tergisus*.

Reproduction occurs in early spring or immediately following the time ice leaves the lakes in Canada (Battle and Sprules, 1960). Spawning takes place in shallow water where an average of 14,000 semibuoyant eggs are shed. The young of the year grow quickly to total lengths up to 15 cm. Maturity is variable with latitude, from 2 to 10 years.

The food of the adult goldeye is primarily benthos. Occasionally small minnows are consumed. Forbes and Richardson (1920) indicate that *H. alosoides* prefers current areas, but Harlan and Speaker (1951) indicate this fish to reach greatest abundance in slack current areas. The goldeye is quite tolerant of silt turbidity but sensitive to industrial pollution.

The goldeye is not recognized as a food fish but can be eaten, hence, this fish has no commercial importance. It is a gamy fighter and will take artificial bait, although it is not actively sought by anglers south of Canadian waters.

Hiodon tergisus

The mooneye (toothed herring, big-eyed shad) is most common

in larger rivers and is more abundant than the goldeye in the Mississippi River. As discussed for the goldeye, this fish has no commercial value and receives only minimal angling attention, although it is a gamy fighter on light tackle and will take artificial and live baits.

Knowledge of the reproduction of _H. tergisus_ is limited. This fish spawns in early spring in shallow water. The young fish grow to total lengths of up to 15 cm in their first year.

The food of the mooneye is primarily micro- and macroinvertebrates. No information is available about specific ecological tolerances or preferences.

Dorosoma cepedianum

The gizzard shad (shad, skipjack, flatfish) is abundant and of ubiquitous occurrence in warmer waters and waters without prolonged ice cover of rivers and lakes and other standing waters associated with rivers.

Reproduction begins in the spring at temperatures over $10^{\circ}C$ and may continue into the summer months. The fish may or may not migrate upstream to spawn but do move from their pelagic habitat to shallow water to spawn. During spawning up to 400,000 demersal, nonadhesive eggs are released which develop in 36 to 100 hours depending on the temperature. The young are zooplanktophagic, occasionally ingesting small benthos and grow rapidly to one-half their adult size in their first

year. The fish mature in 1 to 3 years, depending on latitude; the males mature first.

The adults are primarily phytoplanktophagic, although some zooplankton are utilized for food. Forbes and Richardson (1920) describe the mud-eating habits of the gizzard shad, but this information is not provided by other authors. These fish are tolerant of salinity changes and silt turbidity but are adversely affected by low temperatures.

The gizzard shad has no commercial nor sport fishery value directly but has been considered a valuable forage fish. The utility of gizzard shad as a forage organism for game fish has been questioned due to their rapid growth, and hence the length of time they remain vulnerable to predators, and direct competition with the planktophagic larvae of many game fish (Miller, 1960). Walsh (1953) indicates that frequent winter die-offs of the gizzard shad can cause severe health problems.

Dorosoma petenense

The threadfin shad is abundant in the open-water zone of large lakes and in large rivers, usually in areas of current and eddies, such as behind dams.

Reproduction of threadfin shad occurs in open-water areas in deep water, or occasionally near shore over aquatic vegetation, in the spring when ambient temperature is 21°C. The eggs are adhesive and semibuoyant and sink to the bottom or

to a depth at which the water density equals egg density. The eggs hatch in 3 days at 27°C. The young shad grow approximately 2.5 cm/month until 7 cm long. Early spring hatched fish may spawn the succeeding fall. The fish travel in schools as adults. Lengths greater than 10 cm are rarely attained.

The threadfin shad is planktophagic as an adult. Phytoplankton and zooplankton are consumed in variable quantities in different waters. Detritus has been found to be a major constituent of the diet in some collections (e.g., Ewers and Boesel, 1935).

Current and turbidity are well tolerated by the threadfin. Temperature is a factor controlling the distribution of threadfin shad. Prolonged temperatures below 7°C are usually fatal.

The threadfin has no commercial or sport fishery importance but has proven to be a species with great value as a forage fish.

Alosa chrysochloris

The skipjack (shad, river shad, river herring) is found in low numbers in the channels of large silty rivers but has been found in standing water (Gerking, 1945).

The skipjack spawns in the spring, usually in small aggregations. The exact location of spawning is not known and few details about the life history have been explored.

The skipjack feeds on insects and fish. Larger adults

are almost exclusively piscivorous.

The fish is tolerant of current and silt turbidity. The skipjack has little value as food and is not commercially fished. It is rarely caught by anglers.

Anguilla rostrata

The American eel (common eel, Boston eel, Atlantic eel, freshwater eel) occurs in lakes and streams and is especially common in larger, deep, mud-bottomed rivers in the Mississippi Valley. The American eel is recognized as an excellent food fish but does not seem to have the popularity merited by its table qualities. The commercial eel fishery is minimal and eels caught by sport fishermen are usually taken while fishing for other species.

The eel is noted for its long unknown methods of reproduction. _A. rostrata_ migrates from its freshwater home in lakes and rivers to the Sargasso Sea where a female will spawn 5 to 20 million eggs. The adults die after spawning. The young eels (elvers) remain in the ocean for 2 to 3 years, after which time they return to freshwater to grow and mature.

The American eel has been indicated to be omnivorous in its food habits (Table 10). Eels have been reported to be carnivorous, eating many fish (Harlan and Speaker, 1951), and scavengers, eating dead fish and animal matter (Forbes and Richardson, 1920). No information on current or turbidity

requirements are available. Skin respiration may facilitate respiration in poorly oxygenated waters.

When abundant, eels can be a minor nuisance because of their carnivorous tendency.

Ictiobus cyprinellus

The bigmouth buffalo (common buffalo, lake buffalo, blue buffalo) is widely distributed in lakes and larger streams but prefers slower current areas in deep water over mud bottoms. This fish attains large size (up to 50 pounds) and is commercially important. The combined buffalofish catch in the Mississippi River ranked third in commercial value in 1958 and 1963 (UMRCC, 1967). This fish is of no sport value; specimens are only rarely taken by anglers while fishing for other species.

The bigmouth buffalo moves into sloughs and shallow water extra-channel areas to spawn in mid-April to May in the area of concern. Frequently the onset of reproduction is triggered by rising water levels which permit the bigmouth buffalofish to spawn on the vegetation of inundated areas. Spawning also takes place over mud bottoms. An average of 400,000 eggs are deposited which adhere to vegetation when available. The eggs hatch in 8 to 14 days depending on water temperature. The young grow rapidly and reach lengths of 17 cm after the first growing season. The fish mature in 3 years generally. Adult growth is quite rapid (up to 0.7 kg/year) due to a long growing season.

The adults are benthophagic and eat a wide variety of foods including entomostracans, rotifers, insects, algae, plant seeds, and distillery slops (Forbes and Richardson, 1920). The bigmouth buffalo prefers slow current but is tolerant of current and turbidity.

The bigmouth buffalo is beneficial to the fishery, although in direct competition with other benthophagic fishes, especially the carp.

Ictiobus bubalus

The smallmouth buffalo (roach-back, razor-back buffalo fish, thick lipped buffalo) is similar to the bigmouth buffalo in many characteristics, although the following differences have been noted from the data available. Spawning of the smallmouth buffalo requires rising water levels. This fish does not, in general, attain the size of the bigmouth buffalo but is usually the more abundant of the two species.

Carpoides carpio carpia

The northern river carpsucker (carpsucker, white carp, quillback, silver carp) is quite generally distributed but is most abundant in medium size to large rivers, usually turbid and frequently associated with brush piles. The poor quality flesh and small size are reasons for this fish's poor commercial and sport value.

The northern river carpsucker spawns from April to June, although Bucholz (1957) found ripe females in August and indicated that the river carpsuckers are intermittent spawners. Fecundity is high: an average of 100,000 eggs/female. The eggs are laid randomly and develop in 8 to 12 days. The young grow to 3 to 5 inches at the end of the first growing season. Maturity is reached in 3 years; some males mature in 2 years.

The river carpsucker is benthophagic and consumes great quantities of bottom ooze. The very numerous gill rakers are well adapted to filtering diatoms, green algae, blue-green algae, desmids, protozoa, rotifers, and copepods (in order of decreasing occurrence) from the bottom ooze (Harlan and Speaker, 1951). Insect larvae, primarily dipterans, and molluscs are also consumed. This fish tolerates current and turbid waters.

The river carpsucker has little effect on the fishery, although, due to the feeding habits, this fish may compete to some degree with certain minnows and small channel catfish.

Cyprinus carpio

The carp was introduced from Europe in the late nineteenth century and has become well established in lakes, ponds, and rivers of all sizes. Gerking (1945) indicates that areas with weak currents and mud bottoms are the preferred habitat.

Reproduction occurs in shallow areas of lakes and rivers,

sloughs, and inundated lands in late spring, although spawning frequently continues into the summer. Rehder (1959) indicated the occurrence of multiple spawning. Carp have a very high fecundity; up to 7,000,000 eggs/female have been recorded (Leach, 1919). The eggs are adhesive and attach to masses of vegetation in small bunches. The eggs develop in 3 to 20 days depending on temperature. The young of the year frequently seek shelter in vegetation and may reach 1 pound by the end of the first growing season. Maturity is generally reached in 2 to 4 years. Growth is rapid and attained weights in excess of 20 pounds are not uncommon.

Carp are omnivorous in their feeding habits and rely most heavily on benthos, although plankton are consumed. Insects and plant material are the primary foods.

The carp is tolerant of a wide range of current, turbidity, and pollutional conditions.

Carp migrate into shallow waters to spawn and frequently migrate into the shallows daily to feed. Concerning general migratory tendencies, the carp has been recorded to migrate upstream (Rehder, 1959), and downstream (Thompson, 1933). Luce (1933) described the carp as nomadic.

The wide tolerances, and often extreme abundance make the carp a commercially important species. Carp receive a considerable amount of angling pressure, especially near urban areas.

Carp exert a negative effect on a sport fishery. Luce (1933) indicates that carp serve as forage for game fish, but the advantage is necessarily limited by this fish's rapid growth to nonvulnerable sizes. The carp create an unfavorable habitat by increasing the turbidity and uprooting aquatic vegetation. The carp also compete with other benthophagic fishes for food.

Notemigonus crysoleucas

The golden shiner is widely distributed in lakes, ponds, streams, and backwater areas. The preferred habitat is weedy areas with a mud or mud and debris bottom.

The information available on the reproduction of the golden shiner indicates that this fish broadcasts adhesive eggs over beds of vegetation and algal mats. Spawning begins in the spring and extends through the summer. After hatching the young seek shelter in dense vegetation. Most individuals reach maturity and spawn after 1 year of growth.

Golden shiners are omnivorous and feed on zooplankton, phytoplankton, insects, and filamentous algae. Various authors disagree as to whether the preferred food is zooplankton or phytoplankton. (See Carlander, 1969.)

The golden shiner is quite tolerant of wide ranges of current and turbidity conditions. Gerking's (1945) collections indicated this fish's tolerance of polluted conditions.

The golden shiner is important as a bait minnow and a forage fish for larger game fish. Although valuable as a bait fish, this fish has little importance to the commercial fishery of the river; most production of golden shiners occurs under controlled conditions in ponds.

Pimephales notatus

The bluntnose minnow is widely distributed and abundant in all sizes of lakes and streams; greatest abundance is reached in smaller streams and rivers.

Reproduction begins in May and continues into August. *P. notatus* is considered an intermittent spawner (Starrett, 1951). A mature female produces an average of 2,000 eggs/year, which are spawned at different separate times. The adhesive eggs are deposited on the under surface of logs, stones, large rubble, etc. The eggs hatch in 7 to 14 days, depending on temperature.

Most studies indicate that the bluntnose minnow feeds on small organisms and debris about equally from the plankton and from the bottom. Hankinson (1908) reported consumption of fish eggs.

The small size, trophic level, and abundance makes the bluntnose minnow important to the fishery as a source of forage for larger piscivorous fishes. The extent to which this fish eats the eggs of other fish may indicate this fish to be somewhat detrimental to the fishery.

Pimephales vigilax

The bullhead minnow is widely distributed in streams, and occurs in some lakes. Greatest abundance has been observed in large rivers.

Spawning occurs May to August. No other information on reproduction is available.

P. vigilax is an omnivorous feeder, and like *P. notatus*, frequently ingests large quantities of mud. In addition, the bullhead minnow feeds on aquatic and terrestrial insects.

As *P. notatus*, *P. vigilax* is important to the fishery as a forage organism for piscivorous species.

Hybognathus nuchalis

The silvery minnow is found in many lakes and ponds but prefers the slower, turbid waters of large rivers and back-water areas such as oxbows, overflow ponds, and slack water behind dams.

Reproduction begins in May and extends into the summer. Carlander (1969) indicates that *H. nuchalis* is an intermittent spawner. Other authors indicate a brief spawning period. Breder and Rosen (1966) state that this fish spawns in the same areas as carp, and therefore must spawn before the growth of dense vegetation begins. The fish migrate into coves and quiet areas near shore prior to spawning. An average of 3,000 eggs/female are spawned directly on the bottom ooze. No

information is available about hatching time. Growth is rapid and sexual maturity is reached in 1 year.

The food of the silvery minnow is plant material. Forbes and Richardson (1908) found that the gut contents of this fish was fine mud and diatoms, filamentous algae, and other vegetable forms.

H. nuchalis appears to tolerate running water conditions but prefers slack current areas. This fish is quite tolerant of turbidity.

This fish is valuable to the fishery as forage for piscivorous fish. This fish has no commercial value. Its use as a bait fish is restricted by its softness, and therefore is difficult to hold on a hook.

Notropis lutrensis

The plains red shiner is of general occurrence in lakes and streams and attains greatest abundance in large turbid rivers.

Various authors indicate different spawning times, but all records indicate spawning to occur from late spring through summer. Spawning occurs in inundated weedy areas. N. lutrensis matures and spawns after 1 year. No other specific information is available for this species.

The food of N. lutrensis consists of algae, small crustaceans, and insects.

Based on collection records, the plains red shiner shows wide tolerances to current velocity and turbidities.

This fish is important to the fishery as a forage fish. Because of the small size, this forage fish remains vulnerable to larger predatory fish.

Notropis atherinoides

The emerald shiner is a common inhabitant of rivers and lakes. It prefers open waters, with a moderate current and usually high turbidities. When found, this fish frequently occurs in large schools.

This fish spawns from late spring through summer. The eggs are released near the surface in open water and develop within 24 hours.

The emerald shiner eats a wide range of food, primarily entomostraca, and terrestrial insects. Specimens have been found with amphipods, benthic invertebrates, and filamentous algae in their guts.

The wide current and turbidity tolerances, nonspecific spawning requirements, and small size make this fish a valuable source of forage. The emerald shiner also has some economic value as a bait fish.

Hybopsis storeriana

The silver chub (Storer's chub) occurs in most waters

but seems to prefer the open, turbid, flowing waters of the channels of large river channels. Gravel, often sand is the most favored substrate.

Spawning takes place June to July. River-dwelling fish migrate into creeks to spawn. Lake inhabitants spawn in open water. A large female will produce 11,000 eggs/spawn.

The food of this larger chub consists primarily of mayflies, chironomids, and amphipods. Mayflies are the preferred food when available.

The silver chub demonstrates wide tolerances to current velocities and turbidity conditions.

This fish may be of some value to the sport fishery as forage for large game fish, but the large size may reduce the benefit of this fish. The feeding habits may indicate severe competition with more valuable fish. This fish has no commercial value.

Fundulus nctatus

The black stripe top minnow (top minnow) occurs in many lakes and streams of all sizes. The preferred habitat is shallow, weedy water with a moderate or sluggish current, over mud or debris bottom. This fish is usually found swimming at the water surface.

Reproduction occurs from late May to June in southern Illinois latitudes. Spawning takes place on weed-filled shore-

lines. Breder and Rosen (1966) report that the eggs are flipped, by the anal fin, individually into the leaves of the aquatic weeds. Hatching takes place in upto 24 days. After hatching the young and subadults seek shelter in the vegetation. Growth is rapid; near adult size is reached by the end of the first growing season. Presumably, because of growth rate, maturity is reached in 1 year.

The primary food of _F. notatus_ is insects. This fish has also been found to consume entomostraca, amphipods, and filamentous algae.

Although preferring sluggish currents, this fish is found under a wide range of current conditions. The top minnow is tolerant of silt turbidity.

This fish is of no commercial value. The small size and habitat and behavior indicate that this fish has some value as a forage species.

Gambusia affinis

The mosquito fish is common in quiet water areas of lakes and rivers and is most abundant in backwater areas.

The reproduction of this fish is peculiar in that _G. affinis_ is viviparous: the young are born alive. Because of viviparity, no specific spawning habitats are necessary. Spawning occurs during the warmer months, May to September, in our latitude, and more than one brood/season is frequently produced.

By multiple reproduction, up to 315 new individuals may be produced per year. Maturity and a size of 3 cm are reached in one growing season.

This fish is adapted to feed on organisms associated with the surface film, and the mosquito fish's food overlaps to a large extent with that of *Fundulus notatus*. This species is rarely found in current areas. No information is available pertaining to turbidity tolerances, but by surface breathing, *G. affinis* can withstand low dissolved oxygen conditions.

This fish has no commercial importance. Although a small fish, and therefore very vulnerable to predation, this fish often seeks shelter in water too shallow for large predators, and is, therefore, only of limited value as a forage fish.

Labidesthes sicculus

The brook silversides (ghost minnow, transparent fish) is a small fish of lakes and streams. This fish is most frequently found at, or near, the water surface, often in large schools.

The breeding season is in mid-June. Spawning takes place in open water. According to Hubbs (1921), the greatest abundance of spawning fish was found over a gravel shoal in moderate current. This is consistent with the observation that the eggs have a sticky, thread-like process that serves as both a flotation organ and subsequently as a holdfast when the egg

comes in contact with an object. After hatching the young form large schools, develop rapidly, and reach adult size and maturity in one growing season.

These fish are tolerant of current conditions but prefer quiet water after the spawning season. Turbidity is not a limiting factor.

The food of the brook silversides is primarily aquatic insects. Some entomostraca are eaten.

This small, open-water fish is a valuable forage item for predacious fish, and is utilized by many game fish. This fish is tender and not hearty, and is not recognized as a good bait minnow. Therefore, this fish has no commercial value.

Aplodinotus grunniens

The freshwater drum (sheepshead, white perch, croaker, grunter, grinder, silver bass) is common to abundant in large, shallow lakes and channel and extra-channel areas of large rivers. This fish is usually found over mud bottoms.

Reproduction occurs in May and June in our latitude. The eggs are pelagic, and no special spawning sites are favored. Most spawning occurs in open water. The eggs develop in 25 to 35 hours depending on temperature. The newly hatched larvae remain at the surface for several days and then form large schools. Despite the vulnerability of the eggs and larvae, they receive little predation from other fish (UMRCC, 1967). The

young attain lengths of 12 cm in their first year of growth. Maturity is reached in 3 to 7 years in males, 5 to 6 years in females.

The drum is primarily benthophagic, feeding on insects. Fish, crustaceans, and mollusks are also consumed. The percentages of each food item vary with season and with bodies of water.

This fish occurs in many current and turbidity situations and appears quite tolerant to both factors. The fish is not tolerant of low dissolved oxygen concentrations.

The drum is quite valuable commercially. The smaller fish (1 to 4 kg) are quite palatable and very abundant in some areas. Although considered a rough fish by some anglers and agencies, this fish will take bait and lures, and is pursued as a game fish by anglers.

One limitation to the value of *A. grunniens* is its frequent predation on some more desirable fish and food competition with yellow perch, white bass, and the smallmouth bass. (Many ictalurids can also be added to this list.)

Ictalurus natalis

The yellow bullhead (brown bullhead, white whiskered bullhead, Mississippi bullhead) is widely distributed but reaches greatest abundance in large streams and rivers.

Breeding begins in May and may extend to July in Illinois

waters. The fish move into shallow water and deposit 2000 to 7000 eggs. Undercut bank, logs, and other forms of shelter are the preferred spawning sites. The eggs hatch in 5 to 10 days. The young fish school and are guarded by the male. The young reach 8 cm during their first year. Maturity is reached in 3 years for most males and females.

Yellow bullheads are omnivorous feeders. Their primary foods are benthic insects. Some fish, and occasionally algae and small vascular plants are consumed. The yellow bullhead also feeds as a scavenger.

I. natalis is a very hardy fish. It tolerates low dissolved oxygen and high turbidities very well. Although it prefers sluggish water, it is found in wide ranges of current conditions.

The flesh of the yellow bullhead is superior in taste to that of the other bullheads, and is quite palatable, but the small size (rarely 1 kg) makes this fish not commercially important. Although not considered a game fish, the yellow bullhead ranks high on the sport fish catch record.

Ictalurus punctatus

The channel catfish (spotted cat, fiddler, channel cat, and catfish) is widely distributed and reaches greatest abundance in moderate to large sized streams.

Reproduction occurs in May and June in Illinois. The

mature fish move into shallow water and spawn 3000 to 8000 eggs. Hollow logs, undercut banks, muskrat dens, and other hollow structures are the preferred spawning sites. The male guards the nest for 6 to 10 days until the young hatch. The young school for several days and then separate but remain in the shallows to feed. Lengths of 15 to 25 cm are attained in the first year. Nearly all fish are mature by age five.

Channel catfish have omnivorous feeding habits. Benthos, primarily insects, are the major food item, but fish become more important with increased age and size.

Channel catfish prefer clear, flowing water but are found in widely different habitats with respect to current and turbidity. This fish is not as tolerant of low dissolved oxygen as other ictalurids.

The wide variety of foods and wide tolerances to current and turbidity impart good survival advantage to this fish, and usually large populations occur.

The size, abundance, and excellent table quality make this fish commercially valuable and popular with anglers.

Ictalurus furcatus

The blue catfish (chucklehead cat, forktail cat, great blue cat) is common in larger rivers and streams and rarely found in lakes.

No information is available pertinent to the reproduction

of the blue cat, but presumably it does not differ greatly from the channel catfish.

The presence of this fish in the Mississippi and Missouri Rivers, and the disappearance of this species from South Dakota reservoirs indicates that this species tolerates current and turbidity, and possibly requires current during at least part of the life cycle.

The food of this fish varies according to different authors and different localities. Brown and Dendy (1961) found the blue catfish to be primarily piscivorous and primarily benthophagic in the Tombigbee and Tensaw Rivers, respectively.

The large size and excellent quality flesh make this fish highly sought after by the commercial and sport fisherman alike.

Pylodictus olivaris

The flathead catfish (shovelhead cat, mud cat, yellow cat, Mississippi cat, goujan, nigger-belly) is common in larger rivers and their associated tributaries and backwaters. This fish is frequently found below dams and in deeper water.

Reproduction begins in May or later at water temperatures of 24°C. This fish moves toward quiet shore water but does not seek water shallower than 3 m. The nest is a hollow in the mud bottom into which 6900 to 11,300 eggs/female are

deposited. These eggs hatch in 6 to 7 days. Growth is rapid; lengths of up to 0.2 m are attained in the first year. Maturity is reached in 3 to 5 years. This is a long lived fish and attains weights of 20 kg; 5- to 10-kg fish are not uncommon.

The flathead catfish is considered entirely piscivorous.

This fish occurs in backwater and main channel areas of silty rivers. Apparently *P. olivaris* is quite tolerant of a range of current conditions and silt turbidity.

This fish is sought to some extent by commercial fishermen and anglers. Possibly attention toward this fish is prejudice against the table quality of the flesh (Jordan and Evermann, 1934). Actually this is an excellent food fish, and its large size and piscivorous habits should make this fish a favorable commercial and sport species.

Morone chrysops

The white bass is found primarily in large, deep lakes, and secondarily in larger rivers. Schools of this fish are abundant in the Mississippi River. The white bass occurs over hard and soft bottom, and in weedy and weedless areas.

Reproduction occurs from April to June, usually in May in Illinois waters. The mature fish seek sand or gravel, shallow shoals with a moderate to strong current for spawning. Frequently migration upstream is necessary to find such conditions. A large, mature female will produce 650,000 to 970,000 eggs

which hatch in 46 hours at $15^{\circ}C$. The young develop rapidly, attaining 10 to 12 cm in the first growing season. Maturity is reached in 2 years.

The food of the white bass is primarily fish, insects, and crustaceans; the frequency of each food varies with season and habitat.

This fish prefers standing water during nonspawning season but occurs in a wide variety of habitats with respect to current velocity. This fish is extremely mobile and will frequent a wide variety of habitat types.

This fish is of little commercial value, but the fair to good quality as food, abundance, mobility, feeding habits, size, and fighting ability rank the white bass high as a sport fish.

Micropterus salmoides

The largemouth bass (largemouth black bass) is found in all habitat types but prefers small ponds, lakes, and back-water areas of rivers. Shallow water, mud bottom and weedy areas are also associated with the greatest abundance.

Reproduction occurs during April to June at water temperatures of 15 to $17^{\circ}C$. Males select spawning sites in shallow water (0.25 to 1 m) without current, and circular nests are made in the mud bottom. Vegetation or rubble is a common characteristic of spawning sites. The mature females produce

2000 to 25,000 eggs, which are guarded by the male and hatch in 9 to 10 days. The young school for several weeks, and then seek shelter in weed beds. Lengths of 10 to 15 cm are reached in the first year of growth. Maturity is reached in 2 to 3 years in Illinois waters. Sizes up to 4 kg are reached by Mississippi River fish, although larger fish are taken from lakes.

Largemouth bass are primarily piscivorous as adults, although large crustaceans and other invertebrates are utilized as food.

Although the largemouth bass prefers standing water, the widespread collections of this fish indicate that wide ranges of current conditions are not inimical. This fish is also tolerant to mild silt turbidity, although highly turbid water can exert a negative effect on spawning success. Rapid decreases in temperature are also inimical to reproductive success.

This fish does not receive the attention of river anglers that it receives in inland lakes (UMRCC, 1967), but the large size, feeding habits, and gaminess make this fish attractive to the angler.

Micropterus punctulatus

The spotted bass (Kentucky bass) is found in large and small streams of slow to moderate current. Unlike the largemouth bass (*M. salmoides*) hard substrates and nonvegetated areas are preferred. Spawning occurs over nests built in

gravel areas. In other characteristics, *M. punctulatus* is very similar to *M. salmoides*.

Lepomis cyanellus

The green sunfish (rubber tail, green perch, sunfish, sand bass) attains abundance in all habitats. The most abundant occurrence is in small and moderate sized streams and weedy areas with mud bottoms.

Reproduction begins in May at temperatures greater than 15°C and extends to August. Nests are constructed on gravel substrate, usually in direct sunlight areas. The young remain in weed areas for shelter and to feed. Maturity is reached by almost all fish in 2 years.

Green sunfish are carnivorous and prefer larger animal foods which include fish, insect larvae, freshwater shrimp and snails.

Although *L. cyanellus* prefers weak current areas, this fish is tolerant of a variety of current conditions and standing water. This fish is also tolerant of turbidity and low oxygen concentrations.

The green sunfish is of no commercial value and only fair sport value. The piscivorous nature, early maturity, and hardiness and tolerance, together with low fishing pressure make this fish a nuisance species in some waters.

Lepomis humilis

The orange-spotted sunfish (redspotted sunfish, pumpkinseed, dwarf sunfish, pigmy sunfish) occurs in all habitats. This fish usually occurs in greatest abundance in flowing water habitats with hard substrates and reduced vegetation.

Reproduction takes place in May and June in Illinois waters. A circular nest is built in gravel substrates in shallow water. Nesting will occur on mud substrate. Mature females have been found with 18,000 to [illegible]3,000 eggs. The young fish reach maturity in 3 years.

The feeding habits and ecological tolerances are similar to the green sunfish.

Like the green sunfish this fish has no commercial and still lower sport value due to its small size. The high fecundity and lack of fishing pressure can result in a buildup of a population of orange-spotted sunfish. The resulting stunt population and the feeding habits of this fish (resulting in competition with more valuable fish) make this fish deleterious in some waters.

Lepomis macrochirus

The bluegill (sunfish, sun perch, bream, pumpkinseed, blue sunfish) is found in practically all waters. Bluegill are most abundant in protected areas with clear, quiet water, beds of vegetation and a sand, gravel or muck bottom.

Bluegill reproduction occurs in May and June in Illinois water at temperatures above 20°C. The males build saucer-shaped nests on sand, gravel, mud, and debris bottoms in 0.6- to 2-m depths. A mature female will deposit up to 49,400 eggs. The eggs hatch quickly and the new fry are protected by the male for several days. The young fish reach lengths up to 6 cm in their first growing season. Maturity is attained in 2 to 3 years. These fish rarely exceed 0.5 kg.

Bluegills feed primarily on aquatic insects and zooplankton. Small fish, fish eggs, snails, molluscs, crayfish, and amphipods are also eaten when available. Some authors have found aquatic plants to comprise the bulk of the diet at certain times of the year. (See Calhoun, 1966.)

Bluegills prefer quiet water but are found in running water habitats. Turbidity has been shown to be detrimental to growth and reproduction (Buck, 1956). Bluegills tolerate dissolved oxygen concentrations greater than 1.0 ppm at temperatures in excess of 28°C.

The size of this panfish, good quality flesh, and catchability on natural and artificial lures makes the bluegill much sought after by anglers.

<u>Lepomis microlophus</u>

The red-ear sunfish (shellcracker) is most common in clear, quiet water with aquatic vegetation but also occurs in large

rivers and associated backwater areas. The red-ear inhabits deeper water than the bluegill.

Reproduction begins in late spring and continues through summer. Multiple spawnings are not uncommon. Nests are built on sand, gravel, or mud bottom in water depths of several centimeters to 3 m. Up to 2400 eggs/female have been recorded. Otherwise reproduction is similar to the bluegill.

As mentioned for the bluegill, turbidity is detrimental to growth and reproduction. The red-ear has a stronger preference for standing water than the bluegill. The red-ear is very susceptible to sudden temperature fluctuations (Rounsefell and Everhart, 1953).

The food of the red-ear consists primarily of benthic invertebrates: insect larvae and molluscs. Filamentous algae and aquatic plants are also consumed.

The red-ear is an important sport fish. The flesh is good quality and it is an acceptable sized panfish. Because this fish occupies deeper water and because of the difference in feeding habits, this fish is not as catchable as the bluegill.

Lepomis megalotis

The longear sunfish is not usually abundant in local habitats. Its greatest occurrence is in shallow, weedy areas with mud, detritus bottom. It is more common in large streams than lakes.

Reproduction occurs from May to August. Nests are built on hard substrate in shallow water with slow to moderate current. The eggs that are deposited adhere to the stones in the nest, or roots of vegetation, if present. The fish mature in 3 years.

The food of L. megalotis is primarily aquatic insect larvae, crustaceans, and fish.

The scanty information available pertinent to ecological requirements indicates that the longear sunfish is tolerant of wide ranges of current conditions.

This fish is of no commercial value and only limited sport value due to lack of abundance and small size.

Lepomis gulosus

The warmouth (warmouth bass, wood bass, mud bass, weed bass) occur in all waters. They usually occur in greatest numbers in waters with a low gradient, soft bottom, and abundant vegetation or other cover. In the Mississippi River, the warmouth is most abundant in backwater areas.

Reproduction occurs in June or July when the water temperature reaches 21 $^{\circ}$C, although females may spawn an indefinite number of times (Larimore, 1957). Nests are built in shallow areas (less than 1.6 m) with vegetation and a lightly silt-covered bottom. The nest is usually near a stationary object (e.g., rocks, stumps, clumps of vegetation) (Larimore, 1957).

The eggs hatch in 35 hours at 25^{o} to $27^{o}C$. The young grow rapidly, reaching 5 cm by the end of the growing season, and often reaching 8 to 10 cm and maturity by the following summer.

The food of the adult warmouth consists of insects, small crustaceans, snails, zooplankton, and fish. Warmouth are more piscivorous than the other sunfishes; fish comprise a large component of the food of warmouth over 13 cm (Lewis and English, 1949).

The warmouth tolerates current, high turbidity, and low dissolved oxygen conditions (Larimore, 1957).

The warmouth is of no commercial importance but is of some importance to the sport fishery. This fish has fair to good quality as a food fish and attains a size large enough to interest panfish anglers. From a fishery management standpoint, the warmouth has several disadvantages. Dense populations can result from low exploitation rates and a high population fecundity due to early maturity. At dense population levels, stunting is not uncommon. The warmouth is also a food competitor with the more valuable largemouth bass. Conversely, in controlled populations, the piscivorous habits of the warmouth qualify this fish as a secondary predator to control populations of small fish (Lewis and English, 1949).

Pomoxis nigromaculatus and *P. annularis*

The black crappie (*P. nigromaculatus*) and the white crappie

(*P. annularis*) are common to abundant in all types of water. Both species prefer standing or weak current waters with vegetation and mud or detritus bottoms. The white crappie has a more southern range and would be expected to be more abundant in the Mississippi River between St. Louis and Cairo.

Reproduction occurs in the spring when water temperature is 15 to 18°C and 18 to 20°C (black and white crappie, respectively). Nests are built near stationary structures, and 1000 to 213,000 eggs are spawned. When possible, the eggs are attached to vegetation or roots. Maturity is reached in 2 to 3 years. Growth to 30 cm or more is common. The crappies are the largest members of the group of fish considered panfish.

The food of both fish consists of aquatic insects, fish, and crustaceans. Fish become increasingly important with increase in size.

The black and white crappie are tolerant of mild current conditions. The white crappie is quite tolerant of silt turbidity, but the black crappie is found in clean waters. In California, vegetation is necessary to maintain a good crappie fishery (Calhoun, 1966).

The crappies are highly rated as a sport fish. They are frequently abundant, reach a large size, and have good table quality. The crappies can be a nuisance to the fishery unless numbers can be controlled.

Stizostedion vitreum

The walleye (pike-perch, walleyed pike, pike, jack fish, jack salmon) is found in larger lakes and rivers. This fish prefers lakes but is found in the channels and side channels of clearer rivers with rock, gravel, or hard clay bottom.

Reproduction occurs in early spring when the water temperature approaches 10°C. Spawning takes place in shallow water over rock or gravel shoals in areas with a moderate current. The fecundity ranges from 23,000 to 50,000 eggs/pound of fish weight. The eggs are broadcast, and hatch in 12 to 18 days, depending on temperature. Growth is rapid; the young of the year attain lengths of 15 cm in the first growing season. The males mature in 2 years and females in 3 years in most waters. Although fish as large as 1 m and 11 kg occur, a 6-kg fish is considered large.

Walleye are voracious predators. The adults are primarily piscivorous, but larger aquatic invertebrates are frequently consumed.

Walleye are tolerant of current and are frequently caught in fast water. The fish avoids turbid waters.

The excellent quality flesh, large size, schooling behavior, and gaminess makes this fish very popular with anglers.

Stizostedion canadense

The sauger (sand pike, river pike, spotfin pike, jackfish,

jack salmon) is known from rivers and ponds and lakes associated with rivers. The sauger is most abundant in the main channel and side channel areas of large rivers with a hard substrate.

Reproduction is like the walleye. The sauger does not grow as fast as the walleye. A maximum length of 10 cm is reached in the first growing season, and the fish mature later in 3 to 4 years.

The food is similar to that of the walleye. Fish are the largest component of the diet.

This fish prefers running water areas and is more tolerant of silt turbidity than the walleye.

The sauger is an important sport species. This is an excellent food fish and reaches sizes large enough to make it a desirable game fish.

<u>Environmental factors</u>:

<u>Current</u>

To consider the effect of various physical and chemical factors on fish, one must consider all species individually, and their life cycles. The species considered are those that have been recorded as present in the current ongoing study of the Mississippi River, St. Louis, Missouri, to Cairo, Illinois.

If the direct effect of current on fish is considered, current is rarely a limiting factor. (See Table 10.) All fish that have been recorded as present are tolerant of at

least mild current conditions.

Current is an important factor in reproduction. From Table 11, it can be seen that 22 species that have been recorded as present require standing water for reproduction. Slack current will occur in the channel border areas, but 15 of the 22 species requiring slack current also require vegetation or some form of rubble or shelter for spawning. These conditions are met most frequently in the extra-channel habitats. Martin and Campbell (1953) stated that a high incidence of young fish were found in Missouri River backwaters, and this indicates the use of these habitats as nursery areas. Barnickol and Starrett (1951) indicated the importance of backwaters and sloughs for fish spawning and noted a reduction in game fish in the section of the Mississippi River with reduced backwater areas. The game fish population increased following impoundment of the Clinch River to form Melton Hill Reservoir (Fitz, 1968). Coker (1930) found game fish and "desirable" commercial fish (e.g., paddlefish, catfish, sturgeon) increased following the formation of Lakes Pepin and Keokuk by the impoundment of the Mississippi River. Richardson (1921) noted that as percent lake acreage (adjacent to the river) decreased, the fish yield decreased more severely.

In addition to the specific advantages of reduced current, the general favorability of reduced current areas to the

production of fishes has been supported by Eggleton (1939) and Fritsch (1903).

Turbidity

Turbidity can affect fish directly and indirectly (Crass, 1969). Silt turbidity can be harmful to fishes by interference with gill functions. This interference with gill functions is due to clogging of the respiratory surface of the gills (Ellis, 1937; Kemp, 1949; Trautman, 1933) and/or actual mechanical damage of the gills (Ellis, 1944; Kemp, 1949).

Silt turbidity can interfere with reproduction. Stuart (1953) found that silt adheres to the chorion of brown trout ova. Hobbs (1937), Shapovalov and Berrian (1940), and Shaw and Maga (1943) have shown the deleterious "smothering" effect of siltation from silt turbidity on redds of various species. Alderdice and Wickett (1958) indicate that siltation prevents the flush of wastes away from the eggs. Langlois (1941) described one of the deleterious effects of turbidity as causing destruction of the spawning beds by siltation.

Silt turbidity can inhibit growth of fish. Buck (1956) found bluegill and red-ear sunfish and largemouth bass to grow faster in clear water. He also found production in clear water (177 pounds/acre) to exceed that in turbid water (117 pounds/acre) in an Oklahoma reservoir.

Turbidity can cause a change in species composition.

Thompson (1941) reported that increased turbidity caused a decrease in sight feeders. This can cause a decrease in game fish, which are sight feeders, and an increase in rough fish. Barnickol and Starrett (1951) describe the Mississippi River below the Missouri River as more turbid and a poorer game fish habitat than the upper reach.

Turbidity indirectly affects the fish via the food chain. Turbidity has been shown to be inimical, in various ways, to phytoplankton, zooplankton, macrophytic vegetation, and benthos. As the food supply of an organism is reduced, it is logical to expect the consumer to decline in number, or to decrease its growth rate. The converse is shown by the increased yield of Lakes Pepin and Keokuk following impoundment. After impoundment, the current and turbidity decreased, and the conditions of existence for the fish, the quantity of fish food, and the conditions necessary for reproduction improved. The result was more fish with a better food supply, and thereby, increased production (Galtsoff, 1924).

Substrate

The importance of substrate type has been discussed for benthos and macrophytic vegetation. Many authors have made comments about the bottom preferences of various fishes, and these references have been used in Table 10 and the description of the biology of each species for convenience. At this poin

it is beneficial to point out that the fishes may not prefer a particular type of substratum, but rather they seek suitable current, depth (Cleary and Greenbank, 1954) and turbidity conditions, and suitable food organisms. It is these conditions that may determine over what substratum type a fish is found, rather than active selection of substratum type by the fish. For these reasons, the precise nature of the bottom is not of great importance. The substrate is important to the fish as a source of shelter (Saunders and Smith, 1962; Hartman, 1965), and we may speak of the shelter preferences of fish. In larger rivers where the bed is relatively smooth, the preference for shelter becomes increasingly clear, and "fish of many species tend to congregate near obstructions, in bays, and along the banks, or anywhere else that offers some shelter" (Hynes, 1970).

If the various types of shelter are considered (e.g., vegetation, fallen logs and tree stumps, rubble, rocks, substrate diversity, any structure that would interfere with current, etc.), it can be seen that extra-channel areas have more and a greater diversity of shelter. The main channel, over short distances, is, conversely, comparatively homogeneous and deleterious to fish which seek shelter (Stuart, 1960).

Again the importance of extra-channel areas to the river fishery has been shown.

Dissolved oxygen

A last factor of the physicochemical environment that can affect fish is dissolved oxygen. Although different species of fish have different oxygen tolerances and requirements, oxygen concentrations below 2.0 ppm, at low temperatures, are considered lethal (Thompson, 1925; Moore, 1942). At warmer temperatures, the minimum oxygen concentrations required increases.

Although oxygen is rarely a limiting factor in lentic environments, due to aeration at the air-water interface, and subsequent mixing, the addition of large amounts of organic matter can cause low oxygen concentrations. Thompson (1925) reported fish moving into backwaters and floodplain lakes during periods of stagnation and low dissolved oxygen. This interaction of dissolved oxygen, primary producers, fish and extra-channel areas will be discussed in the following section.

THE WHOLE SYSTEM AND CONCLUSIONS

The direct effects of the physicochemical factors (current, turbidity, substrate and shelter, and dissolved oxygen) have been discussed, and it has been concluded that the extra-channel areas provide the most favorable conditions of existence for the river fishes recorded as present from St. Louis, Missouri, to Cairo, Illinois. Table 13 lists those fish that are adversely affected, or not affected, based on the

hypothetical physicochemical conditions that would prevail following the loss of the extra-channel areas and a knowledge of the ecological requirements (Table 10) of the fish.

Application of the information presented earlier in this report about the groups which comprise the food web of the fishes should complete our understanding of what is known about the impact of the loss of the extra-channel habitat on the fishes.

Many of the fishes of commercial or sport importance that occur in the river are benthophagic and/or piscivorous. The fish that rely on benthos as a food source are indirectly dependent on zooplankton, phytoplankton, and/or macrophytic vegetation. The fish that serve as prey for the predatory fish may be benthophagic, phytoplanktophagic, or zooplanktophagic. Although most adult commercial and sport fish are benthophagic and/or piscivorous, all of the fish recorded as present are planktophagic for at least a brief period during the early developmental stages. The necessity of plankton in the diet was realized by Forbes and Richardson (1913) who stated that the plankton supply is a good index of the food supply of young fishes. In all cases the food chain start with the primary producers, phytoplankton, periphyton, and macrophytic vegetation, and allochtonous materials. (See Figure 3.) Without the primary producers, the food chain is built on the

Figure 3
Biotic interaction and feeding relationships
of fish (1 of 2 sheets)

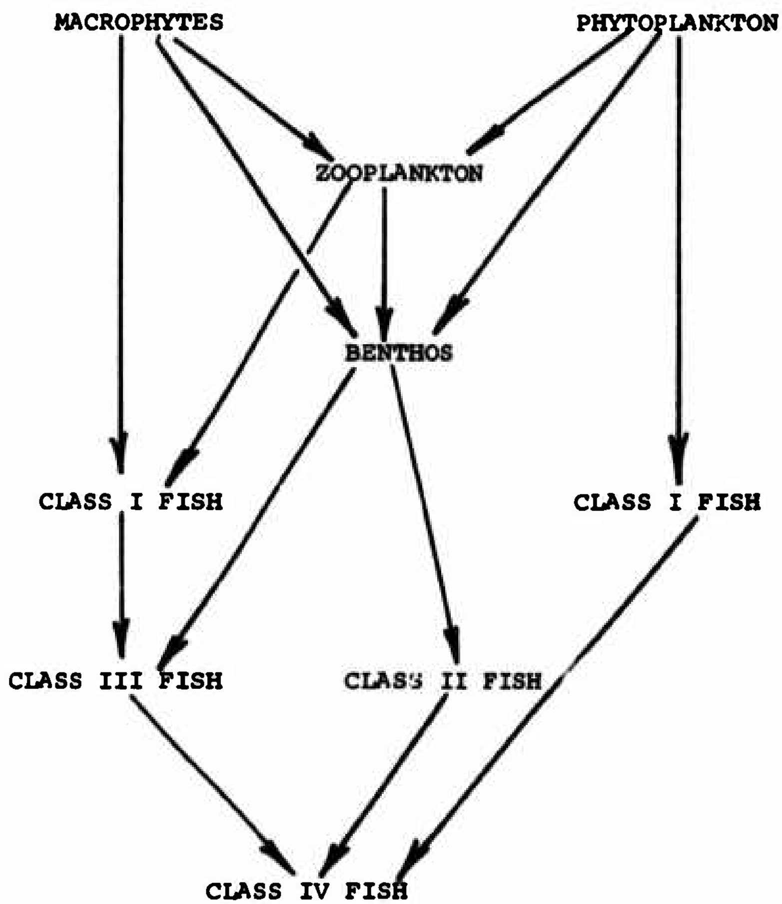


Figure 3 (2 of 2 sheets)

Class I Fish
(Diet primarily plankton)
Dorosoma cepedianum
D. petenense
Notemigonus crysoleucas
Pimephales vigilax
P. notatus
Hybognathus nuchalis
Notropis lutrensis
Gambusia affinis

Class II Fish
(Diet primarily benthos)
Hiodon tergisus
Ictiobus cyprinellus
I. bubalus
Carpiodes carpio
Hybopsis storeriana
Fundulus notatus
Labidesthes sicculus
Aplodinotus grunniens
Ictalurus natalis
Lepomis humilus
L. machrochirus
L. microlophus
L. megalotis

Class III Fish
(Diet primarily benthos and fish)
Anguilla rostrata
Hiodon alosoides
Ictalurus punctatus
Morone chrysops
Lepomis cyanellus
L. gulosus
Pomoxis nigromaculatus
P. annularis

Class IV Fish
(Diet primarily fish)
Amia calva
Lepisosteus osseus
L. platostomus
Ictalurus furcatus
Pylodictus olivaris
Micropterus salmoides
M. punctulatus
Alosa chrysochloris
Stizostedion vitreum
S. canadense

limited amount of allochtonous matter; the quantity of which will vary seasonally with the waters which wash material into the river. When conditions are favorable for primary producers, the amount of utilizable organic matter will increase, and the food supply will be more constant seasonally. An increase in biomass at a lower level will affect an increase in biomass at the next higher level of a food chain. This statement is applicable to fish, whether planktophagic or piscivorous; i.e., the biomass of fish is related to the biomass of food organisms upon which the fish feeds. The abundance of phytoplankton, zooplankton, and benthos has already been shown to be greater in the slack current, extra-channel areas. The following authors offer general support of the increased abundance of food organisms in extra-channel areas: Nikolski (1933), Berg (1948), Forbes (1928), Eddy (1934), Kofoid (1903), Hutchinson (1939), Eggleton (1939), and Fritsch (1903). Because an abundance of plankton is necessary for reproduction of the fishes, plankton becomes more important than as only a supplement to allochtonous organic matter and as a link in the food chain to benthos and planktophagic fish. In addition to the above, and previously cited, information about the abundance of plankton in extra-channel areas, Forbes (1880) supported the need for extra-channel areas: "Running water is relatively destitute of entomostraca, and hence fishes denied access, while breeding,

to slow, or stagnant, water in which entomostraca abound have no chance to multiply." This view is also held by Nikolski (1933). It can be seen that the loss of extra-channel areas will be detrimental to the survival of adult and young fishes.

The rooted aquatic plants and macroscopic algae have been found to be beneficial to fishes as shelter for young fish, spawning sites, aeration of the water, and as a food supply (Pond, 1905; Hotchkiss, 1941; Dill, 1944). Evidence has been provided to support the inimical effect of current on macrophytes, and the benefit of maintaining the extra-channel habitats. It is also appropriate to remind the reader of the previously described improvement in conditions of existence affected by macrophytes.

Lastly, purification of the water will benefit the fish. The benefit can be direct, by removal of toxic organic compounds, or indirect, by maintaining adequate dissolved oxygen levels and providing an environment conducive to the development of food organisms (Wiebe, 1927). The sport fishery will benefit because game fish, rather than rough fish, will be favored by the cleaner water (Medford and Simco, 1971), commercial species will increase, the value of the fish will increase due to improvement in the taste and odor (UMRCBS, 1970; Richardson, 1928), and the incidence of disease will decrease (UMRCBS, 1970). The occurrence of slack water areas is greatly

beneficial to the purification of waters, and, therefore, maintenance of extra-channel areas will aid the provision of cleaner water which is beneficial to the fish.

REFERENCES

Alderdice, D. F., and W. P. Wickett. 1958. A note on the response of developing chum salmon eggs to free carbon dioxide in solution. J. Fish Res. Bd. Canada 15(5): 797-799.

Allen, W. E. 1920. A quantitative and statistical study of the plankton of the San Joaquin River and its tributaries in and near Stockton, California, in 1913. Univ. Calif. Publ. in Zool. 22:1-292.

Bardach, J. 1964. Downstream: A natural history of the river. Harper and Row, N. Y.

Barnickol, P. G., and W. C. Starrett. 1951. Commercial and sport fishes of the Mississippi River between Caruthersville, Missouri, and Dubuque, Iowa. Ill. Nat. Hist. Surv. Bull. 25(5):267-350.

Battle, H. I., and W. M. Sprules. 1960. A description of the semi-buoyant eggs and early developmental stages of the goldeye, Hiodon alosoides (Rafinesque). J. Fish. Res. Bd. Canada 17:245-266.

Berg, K. 1943. Physiographical studies on the River Susaa. Folia Limnol. Scand. 1:174 p.

_____. 1948. Biological studies on the River Susaa. Folia Limnol. Scand. 4:1-318.

Berner, L. M. 1951. Limnology of the lower Missouri River. Ecology 32(1):1-12.

Biological Information Service. 1968-1973. Biological Abstracts. Biol. Information Serv. of Biol. Abstr. Vol. 49-55. Phildelphia, Pa.

Blum, J. L. 1956. The ecology of river algae. Bot. Rev. 22:291-341.

_____. 1960. Algal populations in flowing waters. Spec. Publ. Pymatuning Lab. Field Biol. 2:11-21.

Boruff, C. S. 1930. Illinois River studies, 1929-1930. Ill. Water Surv. Circ. 9. 8 pp.

Breder, C. M., Jr., and D. E. Rosen. 1966. Modes of reproduction in fishes. Amer. Museum of Nat. Hist. Nat. Hist. Pr., New York. 941 p.

Briggs, J. C. 1948. The quantitative effects of a dam upon the bottom fauna of a small California stream. Trans. Amer. Fish. Soc. 78:70-81.

Brook, A. J. 1954. A systematic account of the phytoplankton of the Blue and White Nile at Khartoum. Ann. Mag. Nat. Hist. 12:648-656.

_____, and J. Rzoska. 1954. The influence of the Gebel Aulia Dam on the development of Nile plankton. J. Anim. Ecol. 23:101-114.

Brown, B. E., and J. S. Dendy. 1961. Observations on the food habits of the flathead and blue catfish in Alabama. Proc. S. E. Assoc. Game and Fish Comm. 15:219-222.

Buchholz, M. 1957. Age and growth of the river carpsucker in the Des Moines River, Iowa. Proc. Iowa Acad. Sci. 64:589-600.

Buck, D. H. 1956. Effects of turbidity on fish and fishing. Trans. N. Amer. Wildl. Conf. 21:249-261.

Butcher, R. W. 1927. A preliminary account of the vegetation of the River Itchen. J. Ecol. 15:55.

_____. 1932. Studies in the ecology of rivers. II. The microflora of rivers with special reference to the algae on the river bed. Ann. Bot. 46:813-862.

_____. 1933. Studies on the ecology of rivers. I. On the distribution of macrophytic vegetation in the rivers of Britian. J. Ecol. 21:58-91.

_____. F. T. K. Pentelow, and J. W. A. Woodley. 1931. A Biological investigation of the River Lark. Fishery Invest., London 1(3):1-112.

Calhoun, A. (ed.). 1966. Inland fisheries management. State of California, Dept. of Fish and Game. 545 p.

Campbell, R. S., and J. L. Funk. 1953. The Black River basin in Missouri. Univ. Missouri Studies 26(2):11-21.

Carlander, K. D. 1969. Handbook of freshwater fishery biology, 3rd ed. Wm. C. Brown Co., Dubuque, Iowa. 752 p.

Chandler, D. C. 1937. The fate of typical lake plankton in streams. Ecol. Monogr. 7(4):447-479.

Christenson, L. M., and L. L. Smith. 1965. Characteristics of fish populations in Upper Mississippi River backwater areas. U. S. Bur. Sport Fish. Wildl. Circ. 212. Washington, D. C. p. 20-49.

Chutter, F. M. 1963. Hydrobiological studies on the Vaal River in the Vereigning Area. Part I. Introduction, water chemistry, and biological studies on the fauna of habitats other than the muddy bottom sediments. Hydrobiologica 21(1-2):1-65.

_____. 1969. The effects of silt and sand on the invertebrate fauna of streams and rivers. Hydrobiologica 34:57-76.

Claus, G. 1961. Monthly ecological studies on the flora of the Danube at Vienna in 1957-1958. Verh. int. ver. Limnol. 14:458-465.

Cleary, R. E., and J. Greenbank. 1954. An analysis of techniques used in estimating fish populations in streams, with particular reference to large non-trout streams. J. Wildl. Manage. 18:461-477.

Coker, R. E. 1929. Keokuk dam and the fisheries of the Upper Mississippi River. Bull. U. S. Bur. Fish. 45:87-139.

_____. 1930. Studies of the common fishes of the Mississippi River at Keokuk. U. S. Bur. Fish. Bull. 45(1072):141-225.

Cordone, A. J., and D. W. Kelley. 1961. The influences of inorganic sediment on the aquatic life of streams. California Fish and Game 47:189-228.

Crass, R. S. 1969. The effects of land use on freshwater fish in South Africa, with particular reference to Natal. Hydrobiologia 34:38-56.

Cushing, C. E. 1964. Plankton and water chemistry in the Montreal River lake-stream system, Saskatchewan. Ecology 45:306-313.

Dill, W. A. 1944. The fishery of the lower Colorado River. California Fish and Game 30(3):109-211.

Dorris, T. C. 1958. Limnology of the middle Mississippi River and adjacent waters. Amer. Midl. Natur. 59(1):82-111.

_____, B. J. Copeland, and G. J. Lauer. 1963. Limnology of the middle Mississippi River. IV. Physical and chemical limnology of river and chute. Limnol. Oceanogr. 8(1):79-88.

Eddy, S. 1934. A study of freshwater plankton communities. Ill. Biol. Monogr. 12(4):1-93.

_____, and T. Surber. 1943. Northern Fishes, with special reference to the upper Mississippi valley. Univ. Minnesota Press, Minneapolis, Minn. 276 p.

Edwards, D. 1969. Some effects of siltation upon aquatic macrophyte vegetation in rivers. Hydrobiologia 34:29-37.

Eggleton, F. E. 1939. Fresh water communities. Amer. Midl. Natur. 21:56.

Ellis, M. M. 1931a. A survey of conditions affecting fisheries in the Upper Mississippi River. U. S. Bur. Fish. Circ. 5.

_____. 1931b. Some factors affecting the replacement of the commercial fresh-water mussels. U. S. Dept. Commerce, Bur. Fisheries Fish. Circ. 7. 10 p.

_____. 1936. Erosion silt as a factor in aquatic environments. Ecology 17:29-42.

_____. 1937. Some fisheries problems in impounded waters. Trans. Amer. Fish. Soc. 66(1936):63-71.

_____. 1944. Water purity standards for freshwater fishes. U. S. Fish and Wildl. Serv. Spec. Sci. Rept. 2. 18 p.

Eustis, A. B., and R. H. Hillen. 1954. Stream sediment removal by controlled reservoir releases. Prog. Fish-Cult. 16(1):30-35.

Ewers, L. A., and W. M. Boesel. 1935. The food of some Buckeye Lake fishes. Trans. Amer. Fish. Soc. 65:57-70.

Fish, M. P. 1932. Contributions to the early life histories of 62 species of fishes from Lake Erie and its tributary waters. Bull. U. S. Bur. Fish. 47:293-398.

Fitz, R. B. 1968. Fish habitat and population changes resulting from impoundment of Clinch River by Melton Hill Dam. J. Tenn. Acad. Sci. 43(1):7-15.

Forbes, S. A. 1880. On the food of young fishes. Bull. Ill. Nat. Hist. Surv. 1:71-85.

_____. 1888. Studies of the food of freshwater fishes. Ill. Nat. Hist. Surv. 2(Art. 7):41 p.

_____. 1928. The biological survey of a river system, its objects, methods, and results. Bull. Ill. Nat. Hist. Surv. 17(7):277-284.

_____, and R. E. Richardson. 1908. The fishes of Illinois. Vol. 3 of Final Reports on the History Survey of Illinois. Ill. Nat. Hist. Surv. 357 p.

Forbes, S. A., and R. E. Richardson. 1913. Studies on the biology of the upper Illinois River. Ill. Nat. Hist. Surv. 9(10):95 p.

_____, and _____. 1920. The fishes of ILlinois, 2nd ed. Ill. Nat. Hist. Surv., Springfield, Ill. 358 p.

Fritsch, F. E. 1902. Preliminary report on the phytoplankton of the River Thames. Ann. Bot. 16:571.

_____. 1903. Further observations on the phytoplankton of the River Thames. Ann. Bot. 17:631ff.

_____. 1905. The plankton of some English Rivers. Ann. Bot. London 19:163-167.

Galtsoff, P. S. 1924. Limnological observations in the Upper Mississippi. Bull. Bur. Fish., Washington. 39:347-438.

Gerking, S. D. 1945. Distribution of the fishes of Indiana. Invest. Indiana Lakes and Streams 3:1-137.

Gessner, F. 1961. Der Sauerstoffhaushalt des Amazonas. Int. Revue Ges. Hydrobiol. Hydrogr. 46:542-561.

Griffiths, B. M. 1923. The phytoplankton of bodies of freshwater and the factors determining its occurrence and composition. J. Ecol. 11:184-213.

Hankinson, T. L. 1908. A biological survey of Walnut Lake, Michigan. Mich. State Biol. Surv. Rept. 1907:156-288.

_____. 1919. Notes on life histories of Illinois fish. Trans. Ill. State Acad. Sci. 12:132-150.

Harlan, J. R., and E. B. Speaker. 1951. Iowa fish and fishing. Iowa State Conserv. Comm., Des Moines, Ia. 237 p.

Harrison, A. D., P. Keller, and W. A. Lombard. 1963. Hydrobiological studies on the Vaal River in the Vereiniging Area. Part 2. The chemistry, bacteriology, and invertebrates of the bottom mud. Hydrobiolgia 21:66-89.

Hartman, R. T. 1965. Composition and distribution of phytoplankton communities in the Upper Ohio River. Spec. Publ. Pymatuning Lab. Field Biol. 3:45-65.

_____, and C. L. Himes. 1961. Phytoplankton from the Pymatuning Reservoir in downstream areas of the Shennango River. Ecology 42:180-183.

Hobbs, D. R. 1937. Natural reproduction of quinnat salmon, brown and rainbow trout in certain New Zealand waters. New Zealand Mar. Dept. Fish. Bull. 6:104 p.

Hotchkiss, N. 1941. The limnological role of the higher aquatic plants. In A symposium on Hydrobiology. Univ. Wisconsin Press, Madison, Wisc. 405 p.

Hubbs, C. L. 1921. An ecological study of the life-history of the fresh-water atherine fish *Labidesthes sicculus*. Ecology 2(4):262-276.

Hutchinson, G. E. 1957. A treatise on limnology, Vol. 1. Wiley, New York. 1015 p.

Hutchinson, L. 1939. Some factors influencing zooplankton distribution in the Hocking River. Ohio J. Sci. 39:259-273.

Hynes, H. B. N. 1970. The ecology of running water. Univ. Toronto Press, Toronto, Canada. 555 p.

Jackson, H. W., and W. C. Starrett. 1959. Turbidity and sedimentation at Lake Chautauqua, Illinois. J. Wildl. Manage. 23(2):157-168.

Jones, A. M. 1941. The length of the growing season of largemouth and smallmouth black bass in Norris Reservoir, Tennessee. Trans. Amer. Fish. Soc. 70:183-187.

Jones, J. R. E. 1949. An ecological study of the River Rheidol, North Cardiganshire, Wales. J. Anim. Ecol. 18:67-88.

Jordan, D. S., and B. W. Evermann. 1934. American food and game fishes. A popular account of all the species found north of the equator, with keys for ready identification, life histories, and methods of capture. 3rd edition. Doubleday, Garden City, N. Y. 574 p.

Kajak, Z. 1968. Benthos of oxbow lakes before, during, and after isolation from the river. Ekol. Polska (A) 16(41):822-841.

Kemp, H. A. 1949. Soil pollution in the Potomac River Basin. Amer. Water Works Assoc. J. 41(9):792-796.

Kofoid, C. A. 1903. Plankton studies IV. The plankton of Illinois River 1894-1899 with introductory notes on the hydrography of the Illinois River and its basin. Part I. Quantitative investigations and general results. Ill. Nat. Hist. Surv. 6(Art. 2):535 p.

Kofoid, C. A. 1908. The plankton of the Illinois River, 1894-1899, Part II. Constituent organisms and their seasonal distribution. Bull. Ill. State Lab. Nat. Hist. 8:2-360.

Lakshminarayana, J. S. S. 1965. Studies on the phytoplankton of the River Ganges, Varanasi, India. Part IV. Phytoplankton in relation to fish population. Hydrobiologia 25:171-175.

Lambou, V. S. 1959. Fish populations of backwater lakes in Louisiana. Trans. Amer. Fish. Soc. 88(1):7-15.

Langlois, T. H. 1941. Two processes operating for the reduction in abundance or elimination of fish species from certain types of water area. Trans. N. Amer. Wildl. Conf. 6:189-198.

Larimore, R. W. 1957. Ecological life history of the warmouth (Centrarchidae). Ill. Nat. Hist. Surv. Bull. 27(1):1-83.

Leach, G. C. 1919. Artificial propagation of carp. Econ. Circ. U. S. Bureau Fish. No. 39, 19 p.

Lewis, W. M., and T. S. English. 1949. The warmouth, _Chaenobryttus coronarius_ (Bartran), in Red Haw Hill Reservoir, Iowa. Iowa State College J. Sci. 23:317-322.

Luce, W. M. 1933. A survey of the fishery of the Kaskaskia River. Bull. Ill. Nat. Hist. Surv. 20:71-123.

Ludwig, W. B. 1932. A limnological study of the bottom invertebrates of the Hocking River. Ohio Biol. Surv. 25:223-249.

Lyman, F. E. 1943. A pre-impoundment bottom fauna study of the Watts Bar Reservoir area (Tennessee). Trans. Amer. Fish. Soc. 72:52-62.

MacDonald, R. E. M. 1921. An analytical subject bibliography of the publications of the Bureau of Fisheries. Report. U. S. Commissioner Fish. for 1920, App. V, Bur. Fish. Doc. 899. 306 p.

Marsson, M. 1911. The significance of flora and fauna in maintaining the purity of natural waters, and how they are affected by domestic sewage and industrial wastes. Engineering News 66(9):246.

Martin, R. G., and R. S. Campbell. 1953. The small fishes of Black River and Clearwater Lake, Missouri. Univ. Missouri Studies 26(2):45-66.

Mechanic, S. 1971. Annotated list of selected government publications. Wilson Co., New York. 407 p.

Medford, D. W., and B. A. Simco. 1971. The fishes of the Wolf River, Tennessee and Mississippi. J. Tenn. Acad. Sci. 46(4):121-123.

Mikulski, J. S. 1961. Ecological studies upon bottom communities in the River Wisla (Vistula). Verh. int. ver. Limnol. 14:372-375.

Miller, R. R. 1960. Systematics and biology of the gizzard shad (Dorosoma cepedianum) and related fishes. U. S. Fish. and Wildl. Serv. Fish. Bull. 60:371-392.

Monakov, A. V. 1969. The zooplankton and zoobenthos of the White Nile and adjoining waters in the Republic of Sudan. Hydrobiologia 33:161-185.

Moore, E. 1920. Some plants of importance in pondfish culture. Rep. Commissioner Fish. for 1919. App. 4, pp. 5-20.

Moore, W. G. 1942. Field studies on the oxygen requirements of certain freshwater fishes. Ecology 23:319-329.

Morris, L. A., R. N. Langemeier, T. R. Russell, and A. Witt, Jr. 1968. Effects of main stream impoundments and channelization upon the limnology of the Missouri River, Nebraska. Trans. Amer. Fish. Soc. 97(4):380-388.

Needham, P. R. 1934. Quantitative study on stream bottom foods. Trans. Amer. Fish. Soc. 64:238-243.

Nikolski, G. V. 1933. On the influence of the rate of flow on the fish fauna of the rivers of Central Asia. J. Anim. Ecol. 2:266-281.

O'Connell, T. R., Jr., and R. S. Campbell. 1953. The benthos of Black River and Clearwater Lake, Missouri. Univ. Missouri Studies 26(2):25-41.

Paloumpis, A. A., and W. C. Starett. 1960. An ecological study of benthic organisms in three Illinois River floodplain lakes. Amer. Midl. Natur. 64(2):406-435.

Percival, E., and H. Whitehead. 1930. Biological survey of the River Wharfe. II. Report on the invertebrate fauna. J. Ecol. 18:286-302.

Platner, W. S. 1946. Water quality studies of the Mississippi River. U. S. Fish and Wildl. Serv., Spec. Sci. Rep. No. 30. 75 p.

Pond, R. H. 1905. The biological relation of aquatic plants to substratum. Rep. U. S. Commissioner of Fish. for 1903:483-526.

Purdy, W. C. 1923. A study of the pollution and natural purification of the Ohio River. I. Plankton and related organisms. U. S. Publ. Health Serv. Bull. 131:v-78.

_____. 1930. A study of the pollution and natural purification of the Illinois River. II. Plankton and related organisms. Pub. Health Bull. 198. 212 p.

Rehder, D. R. 1959. Some aspects of the life history of the carp, <u>Cyprinus carpio</u>, in the Des Moines River, Boone County, Iowa. Iowa State College J. Sci. 34:11-26.

Reinhard, E. G. 1931. The plankton ecology of the Upper Mississippi, Minneapolis to Winona. Ecol. Monogr. 1:395-464.

Rice, C. H. 1938. Studies in the Phytoplankton of the River Thames (1928-1932), I and II. Ann. Bot. London, N. S. 2:539-557.

Richardson, R. E. 1913. Observations on the breeding of the European carp in the vicinity of Havana, Illinois. Ill. Nat. Hist. Bull. 9(7):387-404.

_____. 1921. The small bottom and shore fauna of the middle and lower Illinois River and its connecting lakes, Chillicothe to Grafton; its valuation; its sources of food supply; and its relation to the fishery. Ill. Nat. Hist. Surv. Bull. 13:363-524.

_____. 1928. The bottom fauna of the middle Illinois River, 1913-1925. Bull. Ill. Nat. Hist. Surv. 17:387-472.

Rousefell, G. A., and W. H. Everhart. 1953. Fishery science, its methods and applications. Wiley, New York. 444 p.

Ruttner, F. 1963. Fundamentals of limnology. University of Toronto Press, Toronto, Canada. 295 p.

Saunders, J. W., and M. W. Smith. 1962. Physical alteration of stream habitat to improve trout production. Trans. Amer. Fish. Soc. 91:185-188.

Schmidle, W. 1898. Die von Prof. Dr. Volkens und Dr. Stuhlman in Ost-Afrika gessamelten Desmidiaceen, bearbeitet unter Benützung der Vorarbeiten von Prof. G. Hieronymus. Engler's Bot. Jahrb. f. systematik Pflanzengesch u. Pflanzengeogr. 26:1-59.

Schroeder, B. 1899. Das pflanzliche plankton der Oder. Forschungber. Biol. St. Plon. 7:15-24.

Scott, D. C. 1951. Sampling fish populations in the Coosa River, Alabama. Trans. Amer. Fish. Soc. 80:28-40.

Shapovalvov, L. and W. Barrian. 1940. An experiment in hatching silver salmon (Onchorhynchus kisutch eggs in gravel. Trans. Amer. Fish. Soc. 69(1939):135-140.

Shaw, P. A., and J. A. Maga. 1943. The effect of mining silt on yield of fry from salmon spawning beds. California Fish and Game 29(1)29-41.

Spence, J. A., and H. B. N. Hynes. 1971. Differences in benthos upstream and downstream of an impoundment. J. Fish. Res. Bd. Canada 28:35-43.

Sprules, W. M. 1947. An ecological investigation of stream insects in Algonquin Park, Ontario. Univ. Toronto Studies Biol. Ser. 56:1-81.

Starrett, W. C. 1951. Some factors affecting the abundance of minnows in the Des Moines River. Ecology 32:12-27.

_____, and R. Patrick. 1952. Net plankton and bottom microflora of the Des Moines River, Iowa. Proc. Acad. Nat. Sci. Phildelphia 104:219-243.

Stuart, T. A. 1953. Water currents through permeable gravels and their significance to spawning salmonids. Nature 172:407.

_____. 1960. The influence of drainage works, levees, dykes, dredging, etc., on the aquatic stocks. Int. Union. Conserv. Nat. Res. 4(1958):337-345.

Sumner, F. H., and O. R. Smith. 1939. A biological study of the effect of mining debris dams and hydraulic mining on fish life in the Yuba and American Rivers in California. Submitted to the U. S. District Engineer's Office, Sacramento, California. Stanford University, California. 51 p.

Swale, E. M. F. 1969. Phytoplankton in two English rivers. J. Ecology 57:1-23.

Swingle, H. S. 1956. Determination of balance in farm fish ponds. N. Amer. Wildl. Conf. Trans. 21:298-322.

Taft, A. C., and L. Shopovalov. 1938. Homing instinct and straying among steelhead trout (Salmo gairdneri) and silver salmon (Onchorhynchus kisutch). California Fish and Game 24:118-125.

Thompson, D. H. 1925. Some observations on the oxygen requirements of fishes in the Illinois River. Ill. Nat. Hist. Surv. Bull. 15(7):423-437.

_____. 1933. The migration of Illinois fishes. Ill. Nat. Hist. Biol. Notes 1. 25 p.

_____. 1941. The fish production of inland lakes and streams. In: A synposium on hydrobiology. Univ. Wisconsin Press, Madison, Wisc. p. 206-217.

Trautman, M. B. 1933. The general effects of pollution on Ohio fish life. Trans. Amer. Fish. Soc. 63:69-72.

_____. 1942. Fish distribution and abundance correlated with stream gradients as a consideration in stocking programs. Trans. 7th N. Amer. Wildl. Conf., Amer. Wildl. Inst. 211:224.

Upper Mississippi River Conservation Committee. 1967. Fisheries compendium. 238 p.

U. S. Department of Interior. 1972. Sport Fishery Abstracts; Fishery Publication Index, 1920-1954. U. S. Dep. Interior Fish and Wildl. Serv.

U. S. Department of Interior. 1971. Upper Mississippi River comprehensive basin study. Appendix L. Fish and Wildlife. U. S. Dep. Interior Bur. Outdoor Recreation, Lake Central Region, Ann Arbor, Michigan, p. 1-103.

U. S. Monthly Catalog of United States Government Publications. 1972. Supt. Documents, U. S. Government Printing Office, Washington.

Walsh, B. 1953. The "big stink" at Erie. Pennsylvania Angler 22(5):2-4.

Westlake, D. F. 1966. A model for quantitative studies of photosynthesis by higher plants in streams. Int. J. Air Water Pollution 10:883-896.

Whitford, L. A. 1960. The current effect and growth of freshwater algae. Trans. Amer. Micros. Soc. 79(3):302-309.

Wiebe, A. H. 1927. Biological survey of the upper Mississippi River, with special reference to pollution. Bull. U. S. Bur. Fish. 43:137-167.

Zacharias, O. 1898. Das potamoplankton. Zool. Anz. 21:41-48.

Table 1. Physical Factors
A. Main Channel

Reference	Size	Current	Seasonal change	Turbidity	Bottom type
R. Vistula (Mikulski, 1961)			Flooding, frequent oscillations		90% sand, very solid silt deposited during low stages (transit silts)
R. Ganges (Lakshminarayana, 1965)	Large	Fast	Fluctuations of level	High during high water	
R. Dovey (Jones, 1941)	20' wide	Gradient: 330'/mi.			Small stones
R. Dovey (Jones, 1941)	40' wide	Gradient: 50'/mi.			Bedrock, stones, some silt and sand
R. Dovey (Jones, 1941)	90' wide	Gradient: 20'/mi.			Boulders, gravel, silt behind rock
R. Dovey (Jones, 1941)	200' wide	Gradient: 7-10'/mi.			Primarily mud, some sand
R. Tees (Butcher, 1932)		Gradient: .2m/sec.			Gravel
R. Lark (Butcher, et al., 1931)		Slow-flowing	Little fluctuation		Fine gravel and mud
Des Moines R. (Starrett and Patrick, 1952)		Gradient: 1.5'/mi.			
A. 2 mi. above dam B. Below dam C. 2 mi. below dam		Sluggish Swift Moderate			Sand-silt, sand-gravel, sand, gravel, boulders, rubble, silt
Mississippi R. (Reinhard, 1931)		1.5'/sec.		5-70 ppm	Firm sand
St. Croix R. (Reinhard, 1931)	Varies in width	Fast		4 ppm avg.	
Mississippi R. at Quincy (Dorris, et al., 1963)		Fast		1.9-75 ppm	
R. Wharfe (Percival and Whitehead, 1930)					
A. At Grassington		Variable	Great fluctuations: flooding to partial dryness	"Clear"	Stone, gravel
B. At Pool Bridge	0.7-2 m wide				Sand to gravel; hard
C. At Ulleskelf	1-4 m	Uniform, moderate	Flooding		Sand, silt
R. Itchen (Butcher, 1927)	Small, many channels	1/2-5'/sec.			Large stones to mud
Upper Mississippi R. (Galtsoff, 1924)		0.8-3.14'/sec.	Considerable fluctuations	32-995 ppm 8-84 cm	
Ohio R. (Purdy, 1923)					
A. Young		Fast	Fluctuations	23.8 ppm	
B. Stable		Slow	Reduced fluctuations	11.2 ppm	
C. Stable		Slack	Reduced fluctuations	5.8 ppm	
Coosa R. (Scott, 1951)					
A.	500-900' wide	3+'/sec.			Sand, gravel, few mud areas
B.	400' wide 10-15' deep	1-2'/sec.			Mud and debris
Missouri R. (Morris, et al., 1968)					
A. Unchannelized	4-20' deep	Swift		16-275 ppm	Coarse or fine sand with organic matter
B. Channelized	4-20' deep	Swift		53-3000+ ppm	Sand, silt
Black R. (Campbell and Funk, 1953)	Shallow	1.2-3.6'/sec.	Seasonal flooding	16-24 ppm	Gravel; some sand and silt
Missouri R. (Berner, 1951)		3-10'/sec.		<8000 ppm	Gravel and coarse sand

(Continued)

(1 of 3 Sheets)

Table 1. (Continued)
B. Channel Border

Reference	Size	Current	Seasonal change	Turbidity	Bottom type
R. Vistula - Behind regulating dams (Mikulski, 1961)		Moderate to stagnant	Seasonal flooding; changes in water level		Silt-sand; stable
Missouri R. (Morris, et al., 1968)					
A. Mud banks	1-12' deep	Slack			Soft mud
B. Behind pile dikes	10-28' deep	Slack to circular			Packed sand with thin organic matter layer
Missouri R. - Behind pile dikes (Berner, 1951)		Slack			Silty ooze
Mississippi R. (Galtsoff, 1924)		0-0.91'/sec.	Considerable fluctuations		
		[illegible]ue Channels			
R. Vistula - Old river channel (Mikulski, 1961)		Stagnant			Silt; stable
Missouri R. (Morris, et al., 1968)	Length: 200'-1+ mi.				
A. Unchannelized			Wide fluctuations: flood to dryness	24-260 ppm	Sand and silt with organic matter
B. Channelized			Rapid fluctuations	34-2000 ppm	Sand and silt with organic matter
Mississippi R. Cottonwood Chute (Dorris, et al., 1963)					
A. Upper chute		Reduced cf. river: 0.6 ft^3/sec.	High water in spring; 2 mos. ice cover	2.7-75+ cm	
B. Lower chute		57% reduction cf. upper chute 0.26 ft^3/sec.	High water in spring; 2 mos. ice cover	4.7-75 cm	
Upper Mississippi R. (Galtsoff, 1924)		0.32-1.0 ft/sec.	Considerable fluctuations		

(Continued)

(2 of 3 Sheets)

Table 1. (Concluded)
D. River Lakes and Ponds

Reference	Size	Current	Seasonal change	Turbidity	Bottom type
Mississippi R. L. Pepin (Reinhard, 1931)	2 mi. wide 22 mi. long avg. depth= 25-35'	Slack		0-10 ppm at outlet	Mud
Mississippi R. L. Keokuk (Ellis, 1931) (Coker, 1929)		Slack		Varies with wind; decreased cf. river	Silt, up to 6" thick; high organic content
Mississippi R. Valley (Dorris, 1958)					
A. Goose L.	63 acres depth = 2-6 1/2'	None	Rare flooding by tributary streams	8-70 JTU	Sand, mud, drab clay
B. Big L.	56 acres depth = 1-4'	None	Fluctuating water level; drought prevented by pumping well water	0-80 JTU	Drab clay, drab clay loam
C. Sand L.	42 acres depth = 1-5'			10-80 JTU	Mud, drab clay loam
D. Mud L.	38 acres depth = 1-5'			10-80 JTU	Drab clay loam
Mississippi R. (Galtsoff, 1924)					
A. L. Keokuk		0-1.0 ft/sec	Wide, rapid fluctuations due to drawdown		Soft mud
B. L. Pepin		None		Greatly reduced	Silt and sand

E. Sloughs

Reference	Size	Current	Seasonal change	Turbidity	Bottom type
Mississippi R. (Christenson and Smith, 1965)					
A. Miller L.	11.9 acres	Slack		320 ppm	
B. Area A.	1.35 acres avg. depth= 2.4'; max. depth=4.5'	None			
C. Area B.	3.36 acres avg. depth= 5.5'; max. depth=9'	None			

(3 of 3 Sheets)

Table 2. Chemical Factors

A. Main Channel

Reference	Dissolved oxygen (ppm)	Alkalinity (mg/liter $CaCO_3$)	Inorganic nutrients	Organic nutrients
R. Ganges (Lakshminaryana, 1965)	2.1-6.8 (highest during rainy season)	44-130 ppm		
Illinois R. (Forbes and Richardson, 1913)	0.48-14.0 (low value from polluted section)			
Black R. - Middle and upper stations (Campbell and Funk, 1953)	6.7-11.1	64-134		
Missouri R. (Morris, et al., 1968)				
A. Unchannelized	7.2-10.9	152-190		
B. Channelized	5.1-10.0	155-232		
Upper Mississippi R. (Reinhard, 1931) Various pollutional levels	1.5-12.7	99-243		High
Mississippi R. - Adjacent to Cottonwood Chute (Dorris, et al., 1963)	4.4-14.2 x=8.8 (seasonal ranges)	101-183 ppm x=132 (seasonal ranges)	TDS=185-682 mg/liter x=335	Total organic solids 67-182 mg/liter x=103
Upper Mississippi R. (Galtsoff, 1924)			200 ppm	
Danube R. (Claus, 1961)	7.5-8.7	8.1-9.9	Conductivity 264-361 x 10^{-6}mhos	BOD=3.0 mg/liter
Vaal R. (Chutter, 1963)				
A. High flow	3.8-5.6	37-61	TDS=72-239 mg/liter; conductivity 112-165 mhos	
B. Low flow	2.5-5.3	44.6-69	TDS=95-309 conductivity 137-452	

B. Channel Border

Reference	Dissolved oxygen (ppm)	Alkalinity (mg/liter $CaCO_3$)	Inorganic nutrients	Organic nutrients
Illinois R. (Forbes and Richardson, 1913)	1.8-11 (low value in polluted section)			
Vaal R. (Chutter, 1963)				
A. High water	5.6-7.8	39-44.5	TDS=91.6-197.3 Conductivity: 147-312 micromhos	
B. Low water	2.5-3.9	45.6-53.2	TDS=91-206 Conductivity: 150-292 micromhos	

(Continued)

Table 2. (Concluded)
C. Side Channel

Reference	Dissolved oxygen (ppm)	Alkalinity (mg/liter $CaCO_3$)	Inorganic nutrients	Organic nutrients
Missouri R. (Morris, et al., 1968)				
A. Unchannelized	7.3-11.1	151-263		
B. Channelized	5.2-12.9	143-237		
Mississippi R. - Cottonwood Chute (Dorris, et al., 1968)				
A. Upper chute	3.6-20.4 $\bar{x}$=9.1 (seasonal range)	110-188 $\bar{x}$=134	TDS=1-1,112 $\bar{x}$=492	Total organic solids 70-198 mg/liter $\bar{x}$=113
B. Lower chute	3.5-24.3 $\bar{x}$=9.4	100-189 $\bar{x}$=133	TDS=285-1062 $\bar{x}$=433	Total organic solids 75-193 mg/liter $\bar{x}$=117
Danube R. (Claus, 1961)	8.9-13.6	8.3 mg/liter carbonate hardness	$264-362 \times 10^{-6}$ mhos	BOD=1.2-3.2 mg/liter per 48 hrs.
D. River Lakes and Ponds				
Illinois R. - Depue L. (Forbes and Richardson, 1913)	12.92			
Mississippi R. - Outlet of L. Pepin (Reinhard, 1931)	3.7-11.9 $\bar{x}$=7.3	105-193 $\bar{x}$=135		Less than in polluted conditions upstream
Mississippi R. (Ellis, 1931)				
A. L. Keokuk	57% saturation (bottom) 60% saturation (surface)			
B. 2 mi. above L. Keokuk	80% saturation (bottom) 83% saturation (surface)			
Mississippi R. - Near Quincy, Illinois (Dorris, 1958)				
A. Sand L.	4-14 (seasonal)	55-240 (seasonal)		
B. Goose L.	2-16 (seasonal)	40-150 (seasonal)		
C. Big L.	4-14 (seasonal)	90-240 (seasonal)		
D. Mud L.	2.5-16 (seasonal)	70-255 (seasonal)		
E. Sloughs				
R. Susaa (Berg, 1943)	Vertical change with slow flow			

Table 3. Chemical conditions of various habitat types in the Mississippi River.*
A. Mile 280 to 275.

.— Cross-sectional stations of the Mississippi River and adjacent waters between Clarksville, Missouri and Louisiana, Missouri. September and December, 1944.

* From Plather, 1946.

Table 3A (cont'd)

Chemical analysis of water samples from the Mississippi River, including sloughs and and lakes flooded in periods of high water (September 1944)

MILE 275

	Stations		Sp. Cond. mho x 10^{-6} @ $25^{\circ}C$	pH	O_2 in p.p.m. R;S/	HCO_3	CO_3	CO_2	Total (N)	NH_3	Mn	Zn	F	Cu	Fe	PO_4	Cl	Ca
						Parts per million												
A	I	SNY	662	7.82	5.62	115.0	0.00	3.50	1.34	1.30	1.30	0.00	0.00	0.00	1.80	0.72	103.20	55.
B	II	BARROW PIT	357	7.35	0.32	96.0	0.00	15.00	3.25	2.08	1.70	0.00	0.00	0.00	3.80	3.90	0.00	39.
	III	CHUTE	354	7.90	5.52	80.5	0.00	1.70	1.09	0.75	0.00	0.00	0.00	0.00	1.20	0.53	1.54	37.
	IV	ISLAND	290	8.00	5.05	83.0	0.00	1.70	1.25	0.77	0.00	0.00	0.00	0.00	1.15	0.53	1.44	57.
	V	ISLAND	289	8.11	5.54	84.5	0.00	1.70	1.23	0.82	0.00	0,00	0,00	0,00	1.16	0.58	0.38	56.
	VI	CHANNEL	341	8.25	5.63	83.0	0.00	1.70	1.13	0.95	0.05	0.00	0.00	0.00	0.95	0.51	2.60	39.
	VII	CHANNEL	326	8.25	5.61	84.0	0.00	1.70	1.08	0.25	0.03	0.00	0.00	0.00	1.21	0.48	2.12	58.
A	VIII	WOODS	362	8.30	7.23	95.0	2.40	0.00	1.42	0.37	0.15	0.00	0.00	0.00	0.70	0.34	2.22	43.
C	IX	ISLAND	363	8.24	5.68	93.0	0.60	0.00	1.22	0.42	0.25	0.00	0.00	0.00	0.61	0.34	0.66	40.
C	X	ISLAND	363	8.36	7.12	92.0	2.00	0.00	1.37	0.37	0.26	0.00	0.00	0.00	0.75	0.41	3.46	44.
C	XI	ISLAND	364	8.51	6.43	92.0	0.60	0.00	1.18	0.35	0.15	0.00	0.00	0.00	0.75	0.34	1.16	44.

R;S.- oxygen method of Rideal and Stewart.
Iron, manganese, zinc, fluoride and copper were determined on acidified samples.

A Slough habitat
B River lake and pond habitat
C Channel border habitat

Table 3A (cont'd)

Chemical analysis of samples of water from the Mississippi River and adjacent waters
(September, 1944)

MILE 278

Stations		Sp.condl mho x 10^{-6} @ 25°C.	pH	O_2 in p.p.m. R.S.	HCO_3	CO_3	CO_2	Total (N)	NH_3	Mn	Zn	F ///	Cu	Fe	PO_4	Cl	Ca
XII	CHUTE	336	8.40	6.00	86.5	0.00	1.70	1.27	0.63	0.07	0.00	0.00	0.00	1.65	0.53	0.28	39.2
C XIII	ISLAND	335	8.34	6.25	86.0	0.00	1.70	1.27	0.67	0.15	0.00	0.00	0.00	1.68	0.57	0.36	41.8
C XIV	ISLAND	336	8.20	4.15	84.0	0.00	2.00	1.20	0.69	0.15	0.00	0.00	0.00	1.58	0.54	0.66	40.5
XV	CHANNEL	340	8.10	5.10	84.5	0.00	1.70	1.15	0.55	0.15	*	0.00	*	1.31	0.52	2.12	39.5
XVI	CHANNEL	344	8.21	6.25	83.0	0.00	2.60	1.11	0.65	0.20	0.00	0.00	0.00	1.42	0.50	0.76	36.5

Iron and manganese determined on acidified samples. Total nitrogen, *zinc=0.0125 p.p.m., and * Copper-0.027 p.p.m., determined by acidified samples concentrated from four liters of water.
R.S.-Method of Rideal and Stewart.

C Channel border habitat

Table 3A (cont'd)

Chemical analysis of samples of water from the Mississippi River and adjacent waters
(September 1944)

MILE 280

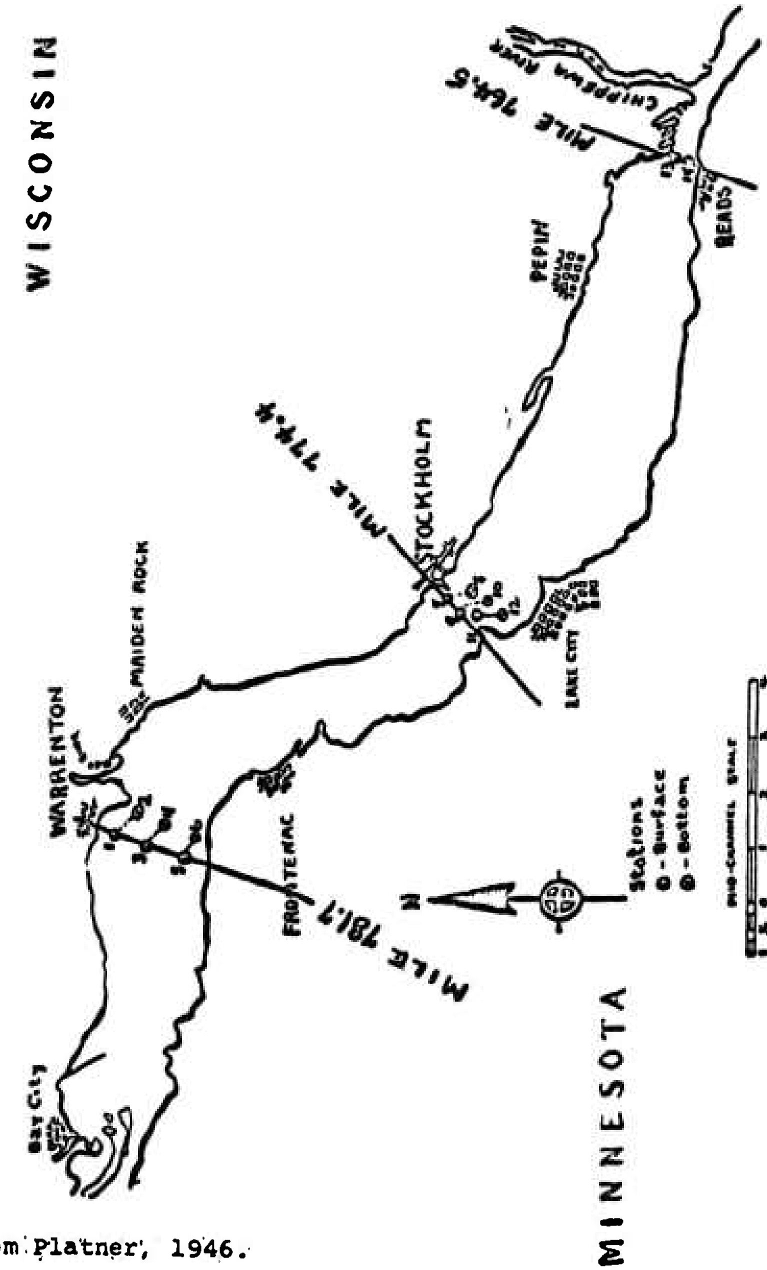
	Stations	Sp. Cond., mho x 10^{-6} @ 25°C	pH	Parts per million													
				O_2 R.S.	HCO_3	CO_3	CO_2	Total	NH_3	Mn	Zn	F	Cu	Fe	PO_4	Cl	Ca
B	XVII SPRING LAKE	212	6.21	4.72	55.5	0.00	1.70	1.66	0.63	0.75	0.00	0.00	0.00	2.10	0.59	0.00	24.4
D	XVIII THE SKY	582	8.10	6.64	95.5	0.00	5.30	1.14	0.96	0.70	0.00	0.00	0.00	1.55	0.56	55.60	47.2
B	XIX SWAN LAKE	297	7.77	6.26	63.5	0.00	1.70	1.84	0.84	0.80	*	0.00	0.00	1.50	0.60	3.86	30.4
B	XX 1903 BREAK	408	7.65	6.80	114.0	0.00	8.80	1.04	0.96	1.95	0.00	0.00	0.00	1.95	0.33	0.70	46.8
B	XXI BARROW PIT	345	7.50	2.45	93.0	0.00	10.50	0.67	0.50	1.20	0.00	0.00	0.00	1.20	1.25	0.96	41.9
C	XXII CHUTE	336	7.90	3.65	83.0	0.00	1.70	1.17	0.46	1.52	0.00	0.00	0.00	1.52	0.52	0.08	36.8
C	XXIII ISLAND	339	8.05	5.40	86.0	0.00	1.70	1.35	0.52	2.00	0.00	0.00	0.00	2.00	0.62	2.12	38.0
	XXIV ISLAND	336	8.20	6/05	85.0	0.00	1.70	1.08	0.50	1.40	0.00	0.00	0.00	1.40	0.55	1.14	38.5
C	XXV CHANNEL	348	8.14	5.35	83.0	0.00	1.70	1.16	0.60	1.35	0.00	0.00	*	1.35	0.46	1.92	38.1
	XXVI TREES	351	8.20	7.55	85.0	0.00	1.70	1.56	0.73	1.70	0.00	0.00	0.00	1.70	0.53	2.50	38.9

Iron and manganese determined from acidified samples.
Total nitrogen, *zinc-p.465 p.p.m., *copper-0.027 p.p.m., determined from acidified samples concentrated from four liters of water.
R.S.--Method of Rideal and Stewart.

B River lake and pond habitat
C Channel border habitat
D Side channel habitat

Table 3. Chemical conditions of various habitat types in the Mississippi River.*

B. Mile 781 to 764. Lake Pepin



Cross-section sampling of Lake Pepin.
(Surface and bottom sample. were collected a few minutes apart)

* From Platner, 1946.

Table 3B (cont'd) .--Physical Characteristics of Lake Pepin (August 20, 1944)

Mile 781.7

	Station See fig. 8	Tur-bidity p.p.m.	Percentage sedimen-tation (60 min.)	Water temp. °C	Air temp. °C	Time	Depth in feet	Sample Depth in feet	Bottom
Upper Lake	1.surface	132	Trace	23.0	20.5	8:45 a.m.	18	3.0	
	2.bottom	213	0.03	23.0	20.5	8:55 a.m.	18	18.0	mud containing bloodworms
	3.surface	113	Trace	23.2	20.5	9:10 a.m.	21	3.0	
	4.bottom	113	Trace	23.2	20.5	9:15 a.m.	21	21.0	mud
	5.surface	81	0.00	23.2	20.5	9:20 a.m.	24	3.0	
	6.bottom	103	0.00	23.2	20.5	9:30 a.m.	24	24.0	mud containing bloodworms

Mile 774.4

	Station	Turbidity	Sedimentation	Water temp.	Air temp.	Time	Depth	Sample Depth	Bottom
Middle lake	7.surface	74	0.00	24.0	22.7	10:30 a.m.	27	3.0	
	8.bottom	100	0.01	24.0	22.7	10:35 a.m.	27	27.0	mud containing bloodworm
	9.surface	70	0.00	24.2	22.7	10:40 a.m.	30	3.0	
	10.bottom	100	0.03	23.0	22.7	10:45 a.m.	30	30.0	" " "
	11.surface	70	0.00	23.7	22.7	10:50 a.m.	39	3.0	
	12.bottom	70	Trace	23.5	22.7	10:50 a.m.	39	39.0	" " "

Mile 764.5

	Station	Turbidity	Sedimentation	Water temp.	Air temp.	Time	Depth	Sample Depth	Bottom
Lower Lake	13.	36	Trace	24.7	24.5	12:10 p.m.	9	4.5	coarse gravel
	14.	43	Trace	23.6	24.5	12:40 p.m.	15	7.5	small shells, [illegible]

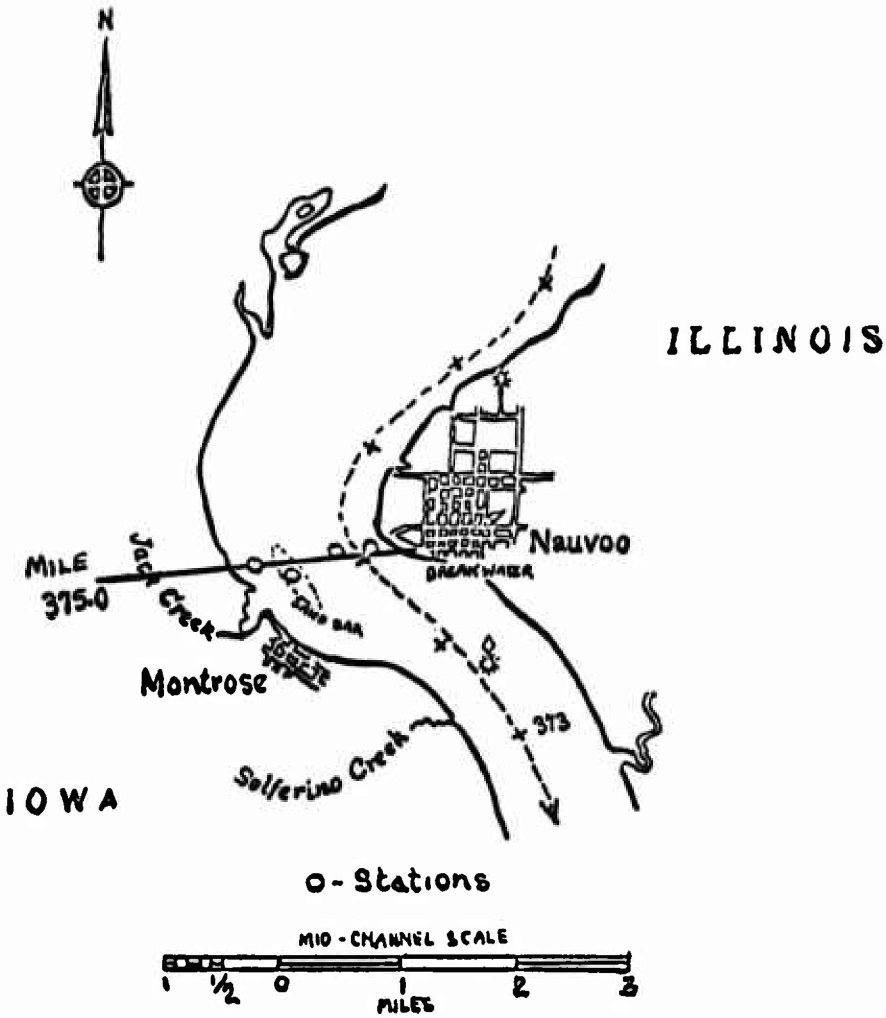
Table 3B (cont'd)

Chemical analysis of water samples collected in Lake Pepin
(August 20, 1944)

Stations (see Figure 8)	Sp.cond. mho x 10^{-6} at 25°C.	pH	Parts per million: Dis-solved oxygen	O.C.	HCO_3	CO_3	NH_3	PO_4	Cl	SO_4	Ca
Mile 781.7											
1 Surface	277.0	8.00	5.03	--	74.2	2.76	--	--	--	--	--
2 Bottom	280.0	8.02	4.18	--	73.7	2.76	--	--	--	--	--
3 Surface	276.0	8.10	3.14	25.5	77.8	2.77	0.28	0.36	1.00	0.00	38.0
4 Bottom	268.0	8.06	3.64	--	70.5	2.76	--	--	--	--	--
5 Surface	264.0	8.20	5.20	--	70.9	3.60	--	--	--	--	--
6 Bottom	276.0	8.14	4.77	--	72.5	2.04	--	--	--	--	--
Mile 774.4											
7 surface	302.0	8.20	3.47	--	80.6	4.20	--	--	--	--	--
8 Bottom	312.0	8.15	3.25	--	81.3	3.60	--	--	--	--	--
9 Surface	270.0	8.18	5.20	25.5	77.8	2.77	0.31	0.33	1.25	0.00	39.5
10 Bottom	277.0	8.18	4.12	--	73.8	2.76	--	--	--	--	--
11 Surface	270.0	8.18	5.20	--	75.0	2.76	--	--	--	--	--
12 Bottom	271.0	8.18	4.61	--	73.3	2.76	--	--	--	--	--
Mile 764.4											
13 Surface	319.0	8.22	5.26	27.0	89.2	3.60	0.31	0.32	2.50	0.00	48.2
14 Surface	323.0	8.12	3.47	--	84.9	2.76	--	--	--	--	--

Table 3. Chemical conditions of various habitat types in the Mississippi River.*

C. Mile 375



- Cross-section sampling of the Mississippi River between Montrose, Iowa, and Nauvoo, Illinois.

* From Platner, 1946

Table 3C (cont'd)

Chemical analysis of samples of water collected across the Mississippi River between Montrose, Iowa, and Nauvoo, Ill. (June 26, 1944)

MILE 375.0

	Stations see fig. 7	Sp. cond. mho x 10^{-6} 25°C	pH	O_2 R. S.	O. C.	HCO_3	CO_3	CO_2	Total (N)	NH_3	PO_4	Cl	SO_4	Ca
							Parts per million							
A	East bank	301	7.80	3.17	26.0	96.0	0.00	Trace	2.16	0.19	0.28	1.70	0.00	34.5
B	Mid channel	291	7.89	3.38	25.0	89.0	0.00	do	3.14	0.28	0.27	1.70	0.00	34.5
A	Sand bar	299	7.83	2.92	27.5	91.5	0.00	do	0.62	0.17	0.28	1.40	0.00	34.6
A	West bank	330	7.89	3.17	34.8	100.0	0.00	do	4.12	0.18	0.28	2.00	5.80	34.5

Note:-Sandbar noted for good fishing for carp and catfish.
Iron, zinc, fluoride, manganese and copper were not detected by methods used.
A trace of CO indicated 1.0 p.p.m. or less.

A Channel border habitat
B Main channel habitat

Table 4. Phytoplankton
A. Main Channel

	Mississippi R. - St. Louis to Cairo (x $10^3/m^3$) Eddy, 1934	Mississippi R. - Keokuk to St. Louis (x $10^3/m^3$) Eddy, 1934	Mississippi R. - Fairport, Iowa. Galtsoff, 1924	Upper Mississippi R. Reinhard, 1931	Upper Mississippi R. Station 5 Wiebe, 1927	Upper Mississippi R. Station 6 Wiebe, 1927	Upper Mississippi R. Station 7 Wiebe, 1927	Upper Mississippi R. Station 9 Wiebe, 1927	Upper Mississippi R. Station 11 Wiebe, 1927	Upper Mississippi R. Station 14 Wiebe, 1927	Rock R. - Sterling, Ill. (x $10^3/m^3$) Eddy, 1934	Ohio R. - Pittsburgh, Ohio Full current Purdy, 1923	Ohio R. - Pittsburgh, Ohio Moderate current Purdy, 1923	Ohio R. - Pittsburgh, Ohio Slack current Purdy, 1923	Hocking R. - Ohio Hutchinson, 1939	R. Thames Rice, 1938
Total Phytoplankton			43 cm^3/m^3													
Cyanophyta																
Microcystis					480/l		660/l	210/l	120/l	60/l						
M. aeruginosa				+							262					
M. flos-aquae			0													
Aphanocapsa				−				90			2398					
Anabaena					240	60		90		18						
A. spiroides			++													
A. planktonica			−													
A. affinis				0												
A. flos-aquae			++	++												
A. circinalis											1042					
Clathrocystis			++					30								
C. aeruginosa																
Aphanizomenon					420											
A. americanum				++												
A. flos-aquae			++	+												
Coelosphaerium				−	960		60	480								
Gloeocapsa				−												
Merismopedia			−	+			120									
Dictyosphaerium																
Gomphosphaeria					60											
Lyngbya					120	45	840	90								
Oscillatoria			0													
O. chlorina				+												
O. limnosa				+												
O. princeps			0	0												
O. tenuis				0												
Chlorophyta																
Pediastrum	0.5	42.4			1720		860	30			181.7					
P. simplex			−	+												
P. duplex			−	0												++
P. boryanum				+												
P. integrum				−												
Closterium			−					30								
C. moniliferum				+												+
C. ehrenbergii				+												
C. gracile				−												+
C. keutzingii				0												−
C. striolatum																−
C. acerosum		0.2									0.3					+
Eudorina																
E. elegans		.+	−	+							4.4					+
Scenedesmus						1,200	3,200	11,320	1,630							
S. minutus			−													
S. quadracauda	0.1	2.0	−	+							12.9					+++
Pleodorina illinoisensis			−													0
Platydorina caudata			−													0
Peridinium																
Actinastrum hantzschii			−													+
Pandorina								60	80							
P. morum				+												+++
Coelastrum microporum																+
[illegible]			−													

A

B

P. boryanum				+												
P. integrum				–												
Closterium			–					30								
C. moniliferum				+												+
C. ehrenbergii				+												
C. gracile				–												+
C. keutzingii				O												–
C. striolatum																–
C. acerosum		0 2									0 3					+
Eudorina																
E. elegans		.+	–	+							44					+
Scenedesmus						1,200	3,200	11,320	1,630							
S. minutus			–													
S. quadracauda	0 1	2 0	–	+							129					+++
Pleodorina illinoisensis			–													O
Platydorina caudata			–													O
Peridinium																
Actinastrum hantzschii			–													+
Pandorina								60	80							
P. morum				+												+++
Coelastrum microporum																+
Cosmarium			–													–
Crucigenia quadrata																–
Dictyosphaerium pulchellum								120								+
Gloeocystis																–
Hydrodictyon reticulatum																
Micractinium pusillum			–													–
Oecystis																–
Quadrigla lacustris																–
Scenedesmus abundans																O
S. bijuga																+
S. dimorphus																+
Staurastrum			–		60											+
S. paradorum																O
S. gracile			–													
Tetraspora				0	1600											
Desmidium				–												
Volvox spermatosphaera				–												
Chlorella					12,800	800	60	800	3600							
Spirogyra			–													+
Stigeoclonium labricum																O
Misc. filamentous																
Chrysophyta												+++	+	O		
Asterionella		371	–			60	60	510	240	120	45.4					
A. formosa				+++												
A. gracillima																+
Melosira					6300	7320	9080	83,500	460	3360						
M. granulata				++												+
M. varians																+
M. crenulata			+++													
Synedra												+				
S. delicatissima			+	++								+++				
S. biceps												+++				
S. ulna				++												+
Fragilaria					200		120	30								
F.mutabilis				+												
F. crotonensis			–	++												+
Stephanodiscus					8260		9000	3090	1320	1660						
S. Hantzschii																+
S. niagarae			O	++												
Cyclotella menenghiana			++	+++												+
Diatoma vulgare				++												+
Nitschia				+		800	6400	1600								+
N. linearis																+
N. recta																+
N. vermiculatus																+
N. acicularis																+
N. sigma																+
N. sigmoidea				O												+
Siurella ovata				+												+
S. angustata																
Thalassiora decipiens																+
Stauroneis acuta																+
Navicula cryptocephala				+++												+
N. viridula																+
Gyrosigma attenuatum																+
G. scalproides				O												
G. spenceri				++												
Synura					[illegible]	[illegible]				[illegible]						

[illegible]																
Misc. filamentous																
Chrysophyta												+++	+	o		
Asterionella		371	-			60	60	510	240	120	454					
A. formosa				+++												
A. gracillima																+
Melosira					6300	7320	9080	83,500	460	3380						
M. granulata				++												+
M. varians																+
M. crenulata			+++													
Synedra												+				
S. delicatissima			-	++								+++				
S. biceps												+++				
S. ulna				++												+
Fragilaria					200		120	30								
F.mutabilis				+												
F. crotonensis			-	++												+
Stephanodiscus					8260		9000	3090	1320	1660						
S. Hantzschii																+
S. niagarae			o	++												
Cyclotella menenghiana			++	+++												+
Diatoma vulgare				++												+
Nitschia				+		800	6400	1600								+
N. linearis																+
N. recta																+
N. vermiculatus																+
N. acicularis																+
N. sigma																+
N. sigmoidea				o												+
Siurella ovata				+												+
S. angustata																
Thalassiora decipiens																+
Stauroneis acuta																+
Navicula cryptocephala				+++												+
N. viridula																+
Gyrosigma attenuatum																+
G. scalproides				o												
G. spenceri				++												
Synura					3260	800				1600						
S. uvella																+
Dinobryon divergens																+
Amphora ovalis				o												
Tribonema minus				-												
Campylodiscus hibernicus				-												
Cocconeis pediculus				++												
C. placentula				++												
Cymbella affinis				+												
Cystopleura turgida				o												
Eunotia				-												
Frustulia rhomboidea				-												
Gomphonema accuminatum				+												
Pleurosigma					17,380	16,045	8 500	800								
Actinastrum							980	30								
Misc. diatoms					8060		240	800	1200	9720						
Pinnularia major				o												
Rhoicosphenia curvata				+												
Sphinctocystis elliptica				o												
S. solea				+												
Stauroneis phoenicenteron				+												

- rare
o common
\+ abundant
++ very abundant
+++ prevalent

Table 4. Phytoplankton
B. Channel Border

	Mississippi R. Behind dike Galtsoff, 1924	Upper Mississippi R. Station 5 Wiebe, 1927	Upper Mississippi R. Station 6 Wiebe, 1927	Upper Mississippi R. Station 7 Wiebe, 1927	Upper Mississippi R. Station 9 Wiebe, 1927	Upper Mississippi R. Station 11 Wiebe, 1927	Upper Mississippi R. Station 14 Wiebe, 1927	Upper Mississippi R. Reinhard, 1931
Total Phytoplankton	33 cm³/m³							
Cyanophyta								
Clathrocystis aeruginosa	o							
Anabaena		135/l	3600/l					
Microcystis		360	60	120/l	90/l			
Aphanocapsa		90		60				
Coelosphaerium		810		60	180	45/l		
Sphaerocystis		90						
Dictyosphaerium				1	30			
Lyngbya			25,200		30			
Chlorophyta								
Pediastrum				800		60		
P. duplex	-							
P. simplex	-							
Scenedesmus		2445		1600	3230	1600	45/l	
S. quadricanda	-							
Actinastrum				135				
A. hantzschii	-							
Staurastrum				800		270	45	
S. gracile	-							
Platydorina caudata	o							
Chlorella		2400		2,400	8,000	18,000	12,000	
Oocystis				1,800				
Crucigenia				820				
Pandorina				2400				
Eudorina	[illegible]				[illegible]			
Closterium						[illegible]		
Ulothrix								+
Mougeotia								+
Zygnema								+
Chaetophora								+
Cladophora								+
Euglenophyta								
Phacus longicaudus	-							
Chrysophyta								
Melosira		10,950	11,100	11,800	70,220	4100	1200	
M. crenulata	+							
Synedra		10,105	46,100	11,440	1100	1600	1600	
S. delicatissima	+							
Fragillaria								
F. crotonensis	-							
Stephanodiscus		9080		11,060	4040	270	590	
S. niagarae	-							
Cyclotella menenghiana	-							
Pleurosigma		22,760		13,720	3260		1600	
Navicula		800		12,300	1720		1600	
Amphora		800				2400		
Synura		45			1600	800		
Nitschia			600					
Epithemia			3,000					
Asterionella				60	310	1520	270	
Actinastrum				240				
Misc. diatoms		1,600	1,200		3200			

- rare
o common
+ abundant
++ very abundant
+++ prevalent

Preceding page blank

A

Table 4. Phytoplankton
C. River Lakes and Ponds

	Mississippi R. Floodplain lakes Dorris, 1958	Mississippi R. Horseshoe L. (x $10^3/m^3$) Eddy, 1934	Upper Mississippi R. Reinhard, 1931	Lake Pepin Galtsoff, 1924	Upper Lake Keokuk Galtsoff, 1924	Lower Lake Keokuk Galtsoff, 1924	Rock R. Slough (x $10^3/m^3$) Eddy, 1934
Total Phytoplankton							
Cyanophyta							
Aphanizomenon flos-aquae	+ + +		+ + +	+ +	O	+	
A. americanum			+ +				
Anacystis inerta	+						
A. montana	+						
Anabaena flos-aquae	+		+ +	+ +	+	+ +	
A. affinis			O				
A. spiroides				+ +	–	+ +	
A. circinalis	+			+ +	O	+ +	
Pleurocapsa minor	+						
Microcystis				+	+	–	
M. aeruginosa	+		O				
Merismopedia			–				
M. tenuissima	+						
Coelosphaerium kuetzingianum	+						
Clathrocystis aeruginosa				+ + +	+	+ +	
Oscillatoria sp.				–		–	
O. aghardii	+						
Cylindrospermum	+						
Lyngbya					O		
Chlorophyta							
Carteria	+						
Gonium							
Pandorina morum	+		+ +				
Volvulina	+						
Eudorina elegans	+	540	–	O	+	+	
Platydorina caudata	+			O	O	+	
Volvox aureus	+						
V. spermatosphaera					O	O	
Uronema	+						
Ulothrix	+		O				
[illegible]							

B

Carteria	+						
Gonium							
Pandorina morum	+		++				
Volvulina	+						
Eudorina elegans	+	54 0	–	0	+	+	
Platydorina caudata	+			0	0	+	
Volvox aureus	+						
V. spermatosphaera					0	0	
Uronema	+						
Ulothrix	+		0				
Micractinium pusillum	+						
Actidesmium	+						
Pediastrum simplex	+		+	+	0	0	
P. biradiatum	+						
P. duplex		0.2	++	+	+	+	
P. integrum			+				
P. boryanum			+				
Coelastrum microporum	+						
Closteriopsis	+						
Dictyosphaerium ehrenbergianum	+						
Oocystis	+						
Selenastrum westii	+						
Tetraedron trigonum	+						
Echinosphaerella limnetica	+						
Treubaria	+						
Trochisia reticularis	+						
Actinastrum hantzschii	+		+	++	+	++	
Scenedesmus accuminatus				0	–	–	
S. bijuga			+				
S. dimorphus	+		+				
S. quadracaudata	+		+++				
S. minutus			+				
Staurastrum				–	–	–	
S. paradoxum	+		+				
S. johnsonii	+						
Closterium				–	–		
C. acerosum		0 3	0				
C. gracile			+				
C. moniliferum			+				
Cosmarium			–				
Crucigenia quadrata			++				
Dictyosphaerium pulchellum			+				
Quadrigula lacustris			+				
Tetraspora			0				
Pleodorina illinoisensis				0	0	+	
Spirogyra			+	–	–		
Mougeotia			0				
Zygnema			0				
Chaetophora			0				
Cladophora			0				
Euglenophyta							

Euglenophyta							
Euglena antifossa	+						
E. acutissima	+						
E. proxima	+						
E. spirogyra	+		o	–		–	
E. acus	+	02	o	–	–		
E. viridis		10	o				
E. oxyurus		40					
E. ehrenbergii			o	–			
E. sp.					–	–	
Phacus longicauda	+	13	o	–	–	–	
P. curvicauda	+						
P. tortus	+						
P. helicoides	+						
Trachelomonas girardiana	+						
T. schaninslandii					+	o	
Chrysophyta							
Tribonema	+						
Synura uvella	+						
Dinobryon	+						
Botryococcus	+		–				
Synedra acus	++						
S. delicatissima				++	–	+	
S. ulna			++				
Pleurosigma	+						
Stephanodiscus	+						
S. niagarae			++	++	–	o	
Asterionella formosa			++				
Cyclotella meneghiana			+++	+	o	+	
Cymbella affinis			+				
Fragillaria crotonensis			+++	+++	o	++	
F. mutabilis			++				
Gyrosigma scalproides			o				
G. spenceri			+				
Melosira granulata			+++				
M. crenulata				+++	+	++	
Navicula			o				
N. confervacea					o	–	
Nitschia			+				
Rhopolodia gibba							
Stauroneis phoenicenteron			+				
Siurirella ovalis			+				
S. biseriata			+				
S. splendida			o				

- rare
o common
+ abundant
++ very abundant
+++ prevalent

Preceding page blank

Table 4. Phytoplankton
D. Side Channel

	R. Thames Rice, 1938
Chrysophyta	
Melosira varians	++
Fragilaria capucina	++
Synedra ulna	++
S. acus	++
Navicula cryptocephala	++
Gyrosigma attenuatum	++
Fragillaria pinnata	+
Synura uvella	+
Asterionella gracillima	o
Amphora ovalis	o
Nitschia linearis	+
N. recta	o
N. sigmoidea	o
N. acicularis	o

o common
+ abundant
++ very abundant

Preceding page blank

Table 4. Phytoplankton
E. Sloughs

	Rock R. Slough Erie, Ill. (x $10^3/m^3$) Eddy, 1934	Hatwood Slough Erie, Ill. (x $10^3/m^3$) Eddy, 1934	Slough near Byron, Ill. (x $10^3/m^3$) Eddy, 1934	Mississippi R. Andalusia Slough Galtsoff, 1924	Mississippi R. Sturgem Bay Galtsoff, 1924
Total Phytoplankton				6.6 cm^3/m^3	5.0 cm^3/m^3
Cyanophyta					
Clathrocystis aeruginosa				o	
Microcystis sp.				o	
Oscillatoria				-	
Anabaena spiroides				+	-
Chlorophyta					
Pediastrum duplex	8.1	10[illegible].2	3.0	+	
P. simplex				o	
Closterium acerosum		53.3	32.0		
Eudorina elegans	1.0			o	+
Scenedesmus caudatus	6.6	46.2		o	-
Actinastrum hantzschii				+	
Staurastrum gracile				-	
Peridinium				-	
Platydorina caudata				o	++
Pleodorina illinoisensis				-	
Euglenophyta					
Euglena viridis	6.6	36.0	96.0		
E. oxyurus	7.8	4.6			
E. acus		73.3	800.0		++
E. spirogyra					++
Phacus longicauda	7.8	75.0		-	
Trachelomonas schaninslandii					++
Chrysophyta					
Melosira crenulata				+	-
Synedra delicatissima				+	-
Fragilaria crotonensis				o	
Stephanodiscus niagarae				o	-
Cyclotella menenghiana				o	-
Pleurosigma spenceri					-

- rare
o common
+ abundant
++ very abundant

Table 5. Typical Communities: Phytoplankton

	Main channel	Channel border	Side channel	River lakes and ponds	Sloughs
Cyanophyta					
Microcystis	+	+		+	+
Aphanocapsa	+	+			
Anabaena	+	+		+	+
Coelosphaerium	+	+			
Merismopedia	+				
Lyngbya	+	+			
Clathrocystis				+	
Aphanizomenon				+	+
Oscillatoria					+
Chlorophyta					
Pediastrum	+	+		+	+
Closterium	+				+
Eudorina	+			+	+
Scenedesmus	+	+		+	+
Pleodorina	+			+	
Platydorina	+				
Pandorina	+			+	
Dictyosphaerium	+				
Tetraspora	+				
Chlorella	+	+			
Volvox				+	
Ulothrix				+	
Spirogyra				+	
Zygnema				+	
Chaetophora				+	
Cladophora				+	
Euglenophyta					
Euglena	+			+	
Phacus	+			+	
Chrysophyta					
Asterionella	+	+			
Melosira	+	+	+	+	+
Synedra	+	+	+	+	+
Fragillaria	+		+	+	+
Stephanodiscus	+	+		+	+
Cyclotella	+			+	+
Diatoma	+				
Nitschia	+		+		
Siurella	+				
Navicula	+	+	+		
Synura	+	+			
Pleurosigma	+	+			
Actinastrum	+			+	
Gyrosigma			+		

+ abundant in all collections

A

	Mississippi R. - St. Louis to Cairo (x $10^3/m^3$) Eddy, 1934	Mississippi R. - Keokuk to St. Louis (x $10^3/m^3$) Eddy, 1934	Mississippi R. - Hastings, Minn. to Alexandria, Mo. Galtsoff, 1924	Mississippi R. Rock Island Rapids Galtsoff, 1924	Upper Mississippi R. Reinhard, 1931	Upper Mississippi R. Galtsoff, 1924	Upper Mississippi R. (no./liter) Wiebe, 1927	Ohio R. - Pittsburgh, O. Full current Purdy, 1923	Ohio R. - Pittsburgh, O. Moderate current Purdy, 1923	Ohio R. - Pittsburgh, O. Slack current Purdy, 1923	Illinois R. Kofoid, 1903	Illinois R. Havana, Ill. Forbes and Richardson, 1913	Rock R. - Sterling, Ill. (x $10^3/m^3$) Eddy, 1934	Hocking R. "Young" stream Hutchinson, 1939	Hocking R. "Mature" stream Hutchinson, 1939	Spoon R. Kofoid, 1903	Missouri R. Berner, 1951	Vaal R. (no./100 liters) Chutter, 1963
Total plankton																		
Total zooplankton			[illegible]	[illegible]				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]		
Protozoa																		
Mastigophora																		
Trachelomonas volvocina													[illegible]					
Synura uvella		+																
Ceratium hirundinella		+											[illegible]					
Peridinium sp.				-	++													
Glenodinium sp.					+													
Sarcodina																		
Difflugia	[illegible]	5						+					4	-	0			
D. lobostoma																		
D. pyriformis																		
D. corona																		
D. lebes																		
Arcella																		
A. vulgaris														0	+			
Centropyxis aculeaton																		
Euglypha																		
Rhizopoda										0								
Ciliata								0	0	0								
Codonella cratera	[illegible]	214			0								[illegible]					
C. lacustris																		
Colpidium																		
Paramecium																		
Stentor					0									0				
Euplotes														0				
Vorticella					0									0	0			
Colpoda					+													
Halteria grandinella					0													
Tintinnidium fluviatile					+								[illegible]					
Rotifera									[illegible]	[illegible]								
Keratella							[illegible]											
K. quadrata	+				+													
K. cochlearis	[illegible]	57			+++	0							[illegible]					
Brachionus																		
B. angularis	8	25											[illegible]					
B. capsuliflorus		[illegible]											[illegible]					
B. calyciflorus	++	[illegible]											[illegible]					
B. budapestinensis	+	+											[illegible]					
B. havanaensis		+											[illegible]					
B. pala																		
B. bakeri																		
B. patulus																		
Polyarthra							[illegible]											
P. trigla	[illegible]	[illegible]			+++								[illegible]					
P. palyptera				0														
Synchaeta																		
S. stylata		[illegible]											[illegible]					
S. pectinata		+											[illegible]					
Asplanchna					+													
A. brightwellii		+											+					
A. amphora																		
Filinia																		
F. longiseta	[illegible]	[illegible]											[illegible]					
Rotifer					+		[illegible]		[illegible]	[illegible]								
Pedalia																		
P. mira	+	+											[illegible]					
Conchiloides natans													[illegible]					
Cathypna																		
Triarthra															0			
T. longiseta																		
Notops																		
N. brachionus																		
Diurella stylata																		
Euchlanis dilatata																		

F. longiseta	[illegible]	[illegible]			+								2					
Rotifer					+	-	24	+	++	++				+	+			
Pedalia																		
P. mira	+	+																
Conchiloides natans													20					
Cathypna													03					
Triarthra														o	o			
T. longiseta						-								-	o			
Notops																		
N. brachionus														o	o			
Diurella stylata						-												
Euchlanis dilatata					-													
Schizocerca diversicornis						-												
Noteus							0452											
Distyla							24											
Monostyla														o	+			
Philodina														o	o			
Pterodina														o	o			
P. patina																		
Rattulus														o	o			
Lecane luna																		
Notholca striata					o													
Trichocera																		
Crustacea									++	+								
Copepoda						[illegible]												
Cyclops							24	-	+	-								
C. viridis	07	o			-													29
C. bicuspidatus	02	+			+								5					
Cyprilla																		
Diaptomus						o	2											
D. oregonensis					-													62
Nauplii					+		39											
Cladocera						[illegible]												
Bosmina																		
B. longirostris	+	o			-								3					
Chydorus																		
Chydorus sphaericus		+																
Diaphanosoma																		
D. brachyurum		+																
D. excisum													21					
D. leuchtenbergianum																		25
Daphnia																		
D. longispina	02	+			o													
D. barbarata																		104
D. dolichocephala																		64
D. pulex					o													
D. retrocurva						o												
D. arcuata																		
Moina							o											
M. micrura																		
M. dubia													40					
M. rectirostris					-	-												[illegible]
M. macrocarpa																		
Ceriodaphnia							o											
Simocephalus																		
Macrothrix																		3
Alona																		
Pleuroxus aduncus																		
Sida crystallina																		2
Dunhevedia setigem																		
Leptodora kindtii																		
Lovenula																		
Drift organisms																		
Baetidae																		1
Baetis glaucus																		
Simulium																		2
Chironomidae																		2
Nematoda																		
Hydra																		
Penta neura																		
Centroptilum medium																		
C. excisum																		
Amphipsyche scottae																		
Coryoneura																		

- rare
o common
+ abundant
++ very abundant

Preceding page blank

Table 6. Zooplankton
B. Channel Border

	Upper Mississippi R. Galtsoff, 1924	Upper Mississippi R. (no./liter) Wiebe, 1927	Upper Mississippi R. Behind dike Galtsoff, 1924	Vaal R. Marginal vegetation Chutter, 1963	Hocking R. Hutchinson, 1939
Total plankton					
Total zooplankton	30 - 330 cm³/m³				
Protozoa					
Rotifera					+
Brachionus					
B. angularis			-		
Keratella		08 - 150			
K. cochlearis			-		
Noteus		1.2 - 140			
Rotifer		06 - 780			
Polyarthra		06 - 40			
Triarthra		04 - 22			
Distyla		06 - 12			
Asplanchna		04 - 0.6			
Crustacea					
Copepoda	640 - 125000 /m³				
Cyclops		08 - 2.4		++	
Parachclops				+	
Harpacticidae				+	
Diaptomus		0.6 - 30			
Simocephalus		24			
Nauplii		9 - 32.4			
Cladocera	2 - 70 /m³				
Bosmina		04 - 4.8			
Daphnia		0.6			
Chydorus		06 - 20		+	
Ceriodaphnia		1.2		+	
Simocephalus				+	
Moina					
M. rectirostris					
Macrothrix spinosa				+	
Alona sp.				+	
Ostracoda					
Stenocypris				+	
Cypridopsis				+	
Pinocypris				++	
Ilyocythere				+	
Cyprilla				+	

- rare
o common
+ abundant
++ very abundant

Preceding page blank

A

Table 6. Zooplankton
C. River Lakes and Ponds

	Upper Mississippi R. Reinhard, 1931	Mississippi R. - Flood-plain lakes near Quincy, Ill. Dorris, 1958	Mississippi R. Horseshoe L. (x $10^3/m^3$) Eddy, 1934	Upper L. Keokuk Galtsoff, 1924	Lower L. Keokuk Galtsoff, 1924	L. Pepin Galtsoff, 1924	Illinois R. Thompson L. Forbes and Richardson, 1913	Illinois R. Quiver L. Forbes and Richardson, 1913	Illinois R. Kofoid, 1903	Hocking R. Behind dam Hutchinson, 1939	Scottish Hill Lochs Replacement quotient=91 days Brook and Woodward, 1956	Scottish Hill Lochs Replacement quotient=26 days Brook and Woodward, 1956	Scottish Hill Lochs Replacement quotient=5 days Brook and Woodward, 1956
Total plankton							77-1180 cm³ [illegible]	185-613 cm³ [illegible]	0.045-11 [illegible]				
Total zooplankton													
Protozoa													
Sarcodina													
Arcella		+								+ +			
A. vulgaris	0			–	–	–							
Difflugia		+								+			
D. pyriformis						0							
D. corona													
D. lebes					–								
D. lobostoma			81 0										
Centropyxis aculeata						–							
Mastigophora													
Trachelomonas volvocina													
Synura uvella			1 6										
Peridinium				–		–							
Ceratium hirundinella				0	–	–		–					
Ciliata													
Frontonia		+											
Lacrymaria		+											
Paramecium		+											
Stentor		+											
S. coeruleus	+			–									
Codonella													
C. cratera	0		0 5										
C. lacustris				0	–	–							
Colpidium										+ +			
Vorticella	+									0			
Colpoda													
Tintinnidium fluviatile	+												
Rotifera													
Asplanchna		+											
A. brightwellii			0 2										
A. amphora				0	+	0							
A. priodonta	+ +				0					+ +			
Brachionus													
B. angularis		+	0 3		+	0							
B. bidentata		+											
B. budapestinensis		+		0									
B. calyciflorus		+ +	0 3										
B. caudatus		+											
B. havanaensis		0											
B. quadridentatus		0											
B. urceolaris		+		0									
B. capsuliflorus													

B

B. patulus													
B. pala				O	++	++							
B. bakeri					O								
Anuraeopsis fissa		+											
Cephalodella gibba		+											
Filinia													
F. longiseta		+	135			O							
F. brachiata		+											
Keratella										++			
K. gracilenta		+											
K. valga		+											
K. cochlearis	+++	++	5	+	+	O							
K. quadrata	+												
Lecane													
L. luna	+	O											
Monostyla													
M. bulla		O											
M. hamata		O											
M. cornuta													
M. lunaris													
Pedalia		+											
P. mira			10			+							
Notholca													
N. accuminata		O											
N. striata	O												
Platyias patulus		O											
Polyarthra										+++			
P. trigla	+++	+	54										
P. palyptera				O	-	O							
Synchaeta		+											
S. stylata				r									
Tetramastax opoliensis		+											
Triarthra										O			
T. longiseta				O	O	O							
Rotifer	+									++			
Euchlanis													
E. dilatata	+			O	O								
Diurella stylata													
Dinocharis paupera													
Schizocerca diversicornis													
Anuraeopsis hypelasma				+		O							
Trichocerca	+												
T. multierinis		O											
T. tenuior		O											
T. pusilla		+											
T. stylata		+											
Conochiloides natans			13										
Cathypna													
C. luna													
Noteus													
N. militaris										+++			
Philodina					+								
Notops													
N. brachionus					+	O				++			
Pterodina													
Rattulus													
R. rattus													
R. pusillus													
R. stylata													
Crustacea													
Copepoda					[illegible]								
Cyclops					+	++							
C. vernalis		++											
C. bicuspidatus	++	O											
C. agilis													+
C. strenuus											+	+	+
C. affinis											+		+
C. viridis			25	++	++	++							
Mesocyclops edax		O											

C

R. rattus													
R. pusillus				-									
R. stylata				-	-	-							
Crustacea													
Copepoda					2000-13,600/m³								
Cyclops				o	+	++							
C. vernalis		++											
C. bicuspidatus	++	o											
C. agilis											-	-	+
C. strenuus											+	+	+
C. affinis											+	-	+
C. viridis			25	++	++	++							
Mesocyclops edax		o											
Eucyclops agilis		o											
Trophocyclops prasinus		o											
Canthocamptus													
C. staphyloides		o									+	+	+
Diaptomus				o	+	++							
D. siciloides		++											
D. gracilis												+	+
D. pallidus			54										
D. oregonensis				+	+	+							
Eugracilis chatauquaensis		+											
Acanthocyclops viridis												+	+
Nauplii				++	++	++							
Cladocera					600-8100/m³								
Daphnia		++											
D. pulex		++											
D. hyalina											+	+	+
D. longispina			20										
D. retrocurva						o							
D. arcuata						o							
Illiocryptus sordidus		o											
Diaphanosoma													
D. brachyurum		+											
D. leuchtenbergianum												+	+
Moina											o	-	o
M. brachiata		+											
M. rectirostris				+	o	-						o	-
M. macrocarpa				+									
Bosmina													
B. longirostris	+	+	2										
B. obtusirostris													
Ceriodaphnia													
C. pulchella		o											
C. reticulata													
Simocephalus											-	+	+
S. vetulus												-	+
Drepanothrix dentat													+
Eurycercus lamellatus												+	+
Acroperus harpae											-	+	+
Alona				-									
Alona affinis											+	+	+
Alonella excisa												+	+
A. nana													+
Rhynchotalona falcata											+	+	+
Peracantha truncata											-	+	+
Polyphemus pediculus												+	+
Sida crystallina					-	o							
Scaphalebris mucronata					-								
Leydigia quadrangularis						-							
Chydorus sphaericus			0 4									+	+
Leptodora kindtii					o	+							
Ostracoda													
Candona crogmania		+											

- rare
o common
+ abundant
++ very abundant

Preceding page blank

Table 6. Zooplankton

aD. Side Channel

	Mississippi R. Prairie du Chien Wiebe, 1931
Total plankton	110 cm³/m³

B. Sloughs

	Rock R. Slough - Erie, Ill. (x 10³/m³) Eddy, 1934	Hatwood Slough - Erie, Ill. (x 10³/m³) Eddy, 1934	Rock R. - Slough near Byron, Ill. (x 10³/m³) Eddy, 1934	Mississippi R. Sturgeon Bay Galtsoff, 1924	Mississippi R. Andalusia Slough Galtsoff, 1924	Illinois R. Kofoid, 1903
Total plankton						9.1 cm³/m
Total zooplankton						
Protozoa						
Mastigophora						
Trachelomonas volvocina	99	109				
Ceratium hirundinella		10	320			
Synura uvella						
Sarcodina						
Difflugia lobostoma	4245	08	320			
Ciliata						
Codonella cratera	103	4549				
Rotifera						
Keratella						
K. cochlearis	.5	610	20			
Brachionus						
B. calyciflorus		71	640			
B. angularis	600	140		-	++	
B. budapestinensis						
B. havanaensis	31					
B. bakeri					o	
B. pala					++	
B. capsuliflorus	103		320			
Polyarthra						
P. trigla	[illegible]	675	10			
P. polyptera				-		
Triarthra longiseta						
Asplanchna amphora					++	
A. brightwellii		93				
Filinia longiseta						
Pedalia mira						
Conchiloides		02				
Conchilus unicornis				-		
Copepoda						
Cyclops				60/m³		
C. bicuspidatus	843	3316				
C. viridis	99	40	1200			
Diaptomus						
D. pallidus	001	25				
Nauplii						
Cladocera						
Chydorus sphaericus	06	12	1440			
Diaphanosoma brachyurum						
Daphnia longiseta	60	363				
Moina brachiata		72				
Sida crystallina				10/m³		

- rare
o common
+ abundant
++ very abundant

Table 7. Typical Communities: Zooplankton

	Main channel	Channel border	Side h	River lakes and ponds	Sloughs
Total zooplankton	0.3-22.7 cm³/m³	3-[illegible] cm³/m³	11.0 cm³/m³	0.965-11.46 cm³/m³	
Protozoa					
Ceratium	+			+	+
Peridinium	+				
Difflugia	+				+
Arcella	+			+	
Codonella	+			+	+
Paramecium	+				
Stentor	+			+	
Vorticella	+				
Trachelomonas					+
Rotifera					
Keratella	+	+		+	+
Brachionus	+				
Polyarthra	+	+		+	+
Synchaeta	+	+			
Filinia	+			+	
Rotifer	+			+	
Pedalia	+			+	
Noteus		+		+	+
Triarthra		+		+	
Asplanchna				+	+
Lecane				+	+
Euchlanis				+	
Rattulus				+	
Cladocera	100-1200 /m³	2-70 /m³		600-8100 /m³	120-200 /m³
Bosmina	+	+		+	
Chydorus	+	+		+	+
Diaphanosoma	+				
Daphnia	+			+	+
Leptodora kindtii				+	+
Sida				+	+
Moina				+	+
Copepoda	1,000-2,[illegible] /m³	640-40,000 /m³		3000-126,000 /m³	60-1840 /m³
Cyclops	+	+		+	+
Nauplii	+	+		+	
Simocephalus		+			
Diaptomus				+	+

+ abundant in all collections

Preceding page blank

Table 8. Benthos
A. Main Channel

	Upper Mississippi R. (no./liter) Wiebe, 1927	Illinois R. (lbs./acre) Richardson, 1921	Illinois R. Havana, Ill. Richardson, 1928	Missouri R. J channelized (mg/m²) Morris, et al., 1968	Missouri R. - Partially channelized (mg/m²) Morris, et al., 1968	Missouri R. Channelized (mg/m²) Morris, et al., 1968	Missouri R. Berner, 1951	Ohio R. - Pittsburgh, O. Full current Purdy, 1923	Ohio R. - Pittsburgh, O. Moderate current Purdy, 1923	Ohio R. - Pittsburgh, O. Slack current Purdy, 1923	Black R. O'Connell and Campbell, 1953	R. Wista Sand bottom Mikulski, 1961	R. Wista Transit silts Mikulski, 1961	R. Wista "Reefs" Mikulski, 1961	R. Dovey - West Wales (no./collection) Jones, 1941	Vaal R. Marginal vegetation Chutter, 1963
Total Berthos																
Tubillaria																
Planariidae															++	
Polycelis nigra											+					
Nematoda										+						
Annelida																
Hirudinea	720	2.4	[illegible]									48/m²				
Haemopis sanquisuga															3	
Herpobdella atomaria															16	
Helobdella stagnalis															4	
Glossiphonia complanata															2	
Oligochaeta		0.2		23-89	248-1,483	11-1,193		+								
Tubificidae			3.94 g/m²								+				++	
Limnodrilus																
Proppapus volki												362/m²	+			
Mollusca												[illegible]/m²	+			
Gastropoda		244	38-89 g/m²		47	2										
Ancyclidae																
Ancyclastrum fluviatile											+			-		
Physidae															4	
Limnaeidae											+					
Lymnaea natalensis											+					+
Bulinus tropicus															35	+
Burnupia																+
Corbicula																-
Planorbidae																+
Pelycepoda		70		54	97-1,032											
Pisidium pussillum																
Unionidae											+					
Sphaeriidae			[illegible] g/m²													
Sphaerium rivicola												18.4/m²				
Amphipoda	8															
Hyalella															++	
Gammarus zaddachi																
Isopoda																
Asellidae											+					
Asellus aquaticus															3	
Trichoptera														6,000/m²		
Rhyacophilidae											+					
Rhyacophila																
R. dorsalis																
Glossosoma boltoni															++	
Hydroptilidae											+					
Ithyetrichia lamellaris															2	
Leptoceridae											+					
Philopotamidae											+					
Helicopsychidae											+					
Hydropsychidae				15-84	1-4	7-38					+					
Hydropsyche				3		22										
H. instabilis																
H. pellucidula															6	
Cheumatopsyche				10-30	3-4	7-16										
Psychomyidae				7-4	45											
Polycentropis				4							+					
Neureclipsis				7	41										4	
Philopotamus montanus																

B

Gammarus zaddachi																
Isopoda																
Asellidae						1					+					
Asellus aquaticus															3	
Trichoptera														6,000/m²		
Rhyacophilidae											+					
Rhyacophila																
R. dorsalis															1	
Glossosoma boltoni															++	
Hydroptilidae											+					
Ithyetrichia lamellaris															2	
Leptoceridae											+					
Philopotamidae											+					
Helicopsychidae											+					
Hydropsychidae				5-36	1-4	7-38					+					
Hydropsyche				13	1	22										
H. instabilis															6	
H. pellucidula																
Cheumatopsyche				8-30	3-4	7-16										
Psychomyiidae				7-14	45						+					
Polycentropis				4											4	
Neureclipsis				7	43											
Philopotamus montanus																
Odontoceridae											+					
Molannidae											+					
Phryganeidae				3							+					
Ptilostomus																
Lepidostomatidae															2	
Lepidostoma hirtum																
Diptera																
Tipulidae																
Dixidae															8	
Ceratopogonidae											+					
Culicidae											+					
Anopheles															3	
Culex															4	
Tabanidae											+					
Simuliidae											+					
Simulium																
Psychodidae											+					
Chironomidae		[illegible]	5.14%	[illegible]	[illegible]	5 000					+++			4000/m²		
Chironomus	3														+	
C. plumosus													50/m²			
C. thummi													1600/m²			
Cryptochironomus													3000/m²			
C. pararostratus												+++	+			
C. detectus												+	+			
Paratendipes connectens												+	+			
Stempellia bausei												+	+			
Stictochironomus													3000/m²			
Tanypus																
Ephemeroptera																
Baetidae																
Ametropus eatoni											+					
Brachycercus				2								O				
Caenis																
Ephemerella															3	
Siphlonurus															+	
Cloeon															+	
Baetis															+	
Heptageniidae															5	
Rithrogena											+					
Ephemeridae				4-297	95-3362	20-44									12	
Ephoron				0-18		20										
Pentagenia				30-226	30	9										
Hexagenia				5-93	95-3103	28-33										
Coleoptera																
Hydrophilidae						3					+					
Parnidae											+					
Gyrinidae											+					
Dytiscidae															2	
Helodidae						4-3									8	
Hemiptera																
Corixidae																
Corixa striata															++	
C. sahlbergei															5	
C. fahlenii															4	
Sigara minutissima															+	
Hydrometridae																
Hydrometra stagnorum															5	
Gerridae																
Gerris najas																

C. defectus												+++	+			
Paratendipes connectens												+	+			
Stempellia bausei												+	+			
Stictochironomus												+	+			
Tanypus													9000/m²			
Ephemeroptera															+1	
Baetidae																
Ametropus eatoni				-2	2						+					
Brachycercus				1-2								o				
Caenis					1											
Ephemerella															5	
Siphlonurus															+	
Cloeon															3	
Baetis															+	
Heptageniidae															5	
Rithrogena											+					
Ephemeridae				+ 257	95-3362	28-44									12	
Ephoron				9-15		20										
Pentagenia				30-228	39	9										
Hexagenia				3-92	95-3308	28-33										
Coleoptera																
Hydrophilidae						3										
Parnidae											+					
Gyrinidae											+					
Dytiscidae											+				2	
Helodidae						+3									8	
Hemiptera																
Corixidae																
Corixa striata																
C. sahlbergi															++	
C. fahlenii															8	
Sigara minutissima															3	
Hydrometridae															+	
Hydrometra stagnorum															5	
Gerridae																
Gerris najas																
G. lacustris																
Veliidae															8	
Velia currens																
Odonata															8	
Libellulidae											+					
Aeschnidae											*					
Coenagrionidae															4	
Ischnura elegans																
Agrionidae											+					
Ealopteryx																
Gomphidae				2	2-43	8-248									4	
Gomphus				1	2-43	240										
Octogomphus						9										
Plecoptera																
Chloroperlidae											+					
Chloroperla															8	
Perlidae																
Perla											+				7	
Nemuridae																
Leuctra																
Nemura															+1	
Neuroptera															22	
Sialidae											+					
Sialis															2	
Lepidoptera																
Pyralidae											+					

- rare
o common
+ abundant
++ very abundant
+++ prevalent

Preceding page blank

Table 8. Benthos
B. Channel Border

	Upper Mississippi R. (no./m²) Wiebe, 1927	Illinois R. (lbs./acre) Richardson, 1921	Missouri R. Steep bank Berner, 1951	Missouri R. Behind pile dike Berner, 1951	R. Wista - Sand and silt in mild current Mikulski, 1961	R. Wista - Sand and silt bottom with no current Mikulski, 1961	Vaal R. Marginal vegetation Chutter, 1963
Total Benthos			217#/A	127#/A			
Turbellaria							
Planariidae							+
Rhabolocoela							+
Prostoma							+
Nematoda							+
Oligochaeta		0 5					
Tubificidae							
Limnodrilus	[illegible]					300/m²	+
Nais							+
Naididae							+
Pristina							+
Hirudinea		4 7					+
Mollusca		9 3					
Amphipoda							
Hyalella azteca	3200-3600						
Tardigrada							+
Trichoptera							
Cheumatopsyche thomasetti							+
Amphipsyche scottae							+
Trianodes falculata							o
Orthotrichia							o
Diptera							
Ceratopogonidae							+
Tipulidae	4						+
Syphridae							–
Empididae							–
Ephydridae							+
Pleidae							o
Chironomidae	36-54	1 0					
Chironomus							
C. thummi					+		
C. plumosus					+		
Allochironomus					+		
Limnochironomus nervosus						+	
Tanytarsus lobatifrons						+	
Trichocladius alagarom						+	
Procladius						+	
Ablabesmyia lentiginosa						+	
Cryptochironomus demeieri						+	
Simuliidae							
Simulium							+
S. memahoni							+
S. nigritarsis							–
S. damnosum							+
Ephemeroptera							
Baetis							+
B. harrisoni							+
B. bullus							+
Centroptilium excisum							+
Pseudocloeon maculosum							+
P. vinosum							+
Austrocloeon							+
A. africanum							o
Caenidae							+
Coleoptera		0 5					
Dytiscidae	•						o
Hydraenidae							o
Elmid							o
Odonata							

o common
+ abundant

A

Table 8. Benthos
C. River Lakes and Ponds

	Mississippi R. Floodplain lakes Dorris, 1958	Illinois R. - Thompson L. With vegetation (lbs./acre) Richardson, 1921	Illinois R. - Thompson L. No vegetation (lbs./acre) Richardson, 1921	Illinois R. Peoria L. Richardson, 1928	Black R. Clearwater L. O'Connell and Campbell, 1953
Porifera					
Meyenia crateriformis	+				
Nematoda					
Limnomermis	O				
Pseudomermis	O				
Oligochaeta			0.1		+++
Tubificidae				3.2-1,292 #/A	
Sparganophilus	+				
Peloscolex multisetosus	+				
Hirudinea		1.6	3.9	3.2-106 1 #/A	+
Glossiphonia fusca	+				
Placobdella montifera	+				
Helobdella stagnalis	+				
Erpobdella punctata	+				
Amphipoda					
Talitridae					+
Mollusca					
Gastropoda		316.5	206.3	14.7 #/A	
Physidae					+
Limnaeidae					+
Ancylidae					+
Ferrissia	+				
Pelycepoda		1.4	10.2		
Unionidae					+
Anodonta grandisi	+				
A. corpulenta	+				

B

[illegible] stagnalis	+				
Erpobdella punctata	+				
Amphipoda					
Talitridae					+
Mollusca					
Gastropoda		316.5	206.3	14.7#/A	
Physidae					+
Limnaeidae					+
Ancyclidae					+
Ferrissia	+				
Pelycepoda		1.4	10.2		
Unionidae					+
Anodonta grandisi	+				
A. corpulenta	+				
Cyrenidae					+
Sphaeridae				0.7-5417.2 #/A	
Decapoda					
Cambarus immunis					+
Palaemonetes					+
Diptera					
Chironomidae		179.5	88.9	132.5#/A	+++
Chironomus dorsalis	+				
C. nervosus	+				
C. crassicandata	+				
Harnischia tenuicaudata	o				
Cryptochiromonus digitatus	o				
C. pararostris	+				
Glyptotendipes lobiferus	+				
Tanypus stellata	+				
Clinotanyous	+				
Coelotanypus concinnus	o				
Procladius adumbratus	+				
P. culiciformis	+				
Culicidae					+++
Chaoborus punctipennis	++				
Psorophora ciliata	+				
Tabanidae					+
Ceratopogonidae					+
Tipulidae					+
Ephemeroptera					
Baetidae					+
Ephemeridae					+
Caenis	+				
Odonata					
Coenagrionidae					
Ischnura verticulis	o				
I. posita	o				
Enallagma signatum					
Agriumidae					+
Agriaviolacea	o				
Aeschnidae					

P. culiciformis	+				
Culicidae					
Chaoborus punctipennis	++				+++
Psorophora ciliata	+				
Tabanidae					+
Ceratopogonidae					+
Tipulidae					+
Ephemeroptera					
Baetidae					+
Ephemeridae					+
Caenis	+				
Odonata					
Coenagrionidae					
Ischnura verticulis	o				
I. posita	o				
Enallagma signatum					
Agriumidae					+
Agriaviolacea	o				
Aeschnidae					+
Nasiaeschna	o				
Gomphidae					+
Gomphus submedianus	o				
Libellulidae					
Heleidae					
Atrichpogon	+				
Palpomyia	+				
Ephydridae					
Parydra	+				
Coleoptera					
Hydrophilidae					+
Parnidae					+
Gyrinidae					+
Hemiptera					
Trichocoriea verticalis	+				
Sigara alternata	+				
Trichoptera		1.7	1.1		
Leptoceridae					+
Heliopsychidae					+
Hydropsychidae					+

o common
+ abundant
++ very abundant
+++ prevalent

Preceding page blank

Table 8. Benthos
D. Side Channel

	R. Wista Old channel Mikulski, 1961
Oligochaeta	
Tubifex tubifex	11,000/m²
T. barbatus	
Mollusca	
Gastropoda	1550/m²
Diptera	
Chironomidae	1631/m²
C. plumosus	+++

A

Table 10. Ecology of the fishes recorded as pres

Fish	Habitat	Food	Migration/Mobility	Abundance	Size	Commercial importance	Sport importance	Relationship with other fish
Amia calva	General distribution; prefer sluggish waters and weedy areas	Primarily piscivorous; some molluscs and crayfish	Migrate into shallow backwaters to spawn	Frequently abundant	1 1/2'-2' (3')	None; can be eaten with correct preparation	Good fighting	Detrimental; voracious predator
Lepisosteus osseus	Large rivers, lakes, ponds, sloughs; prefer areas with logs, weeds, brush, mud and sand bottom	Piscivorous; small fish	Move into shallows to spawn	Abundant	2.2 m	None	Good fighting	Predator
Lepisosteus platostomus	Large rivers, lakes; prefer channels of large, silty rivers, with hard bottoms and no vegetation	Piscivorous	Often move into shallows or flooded areas, or upstream from lakes	Abundant	2.5 m	None	Good fighting	Predator
Anguilla rostrata	Lakes and rivers; prefer larger streams, deep water with mud bottom	Carnivores; scavengers of dead fish and animal matter; omnivorous	Catadramous	Rare	1-2 m	Valuable food	None	
Hiodon alosoides	Lakes and rivers; prefer large, silty streams and oxbow lakes	Insects, molluscs, small minnows		Rare	0.4 m	None; poor food fish	Some game value where abundant; will take artificial lure	
Hiodon tergisus	Lakes and large rivers	Primarily invertebrates including plankton		More common than H. alosoides		None	Game fish, will take artificial lure	
Dorosoma cepedianum	Lakes, large rivers, backwater areas; prefer open waters over mud bottoms	Debris, phytoplankton, zooplankton, some benthic and nektonic fauna	Some movement, associated with spawning; upstream or in to shallows	Very abundant	.25 m	None	Forage	Forage
Ictiobus cyprinellus	Lakes and rivers; prefer slower current over mud bottom, deep water	Benthophagic; macro and microinvertebrates, algae, detritus	Upstream migration into sloughs to spawn	Up to 600 lbs. per acre	1 m 50 lbs.	Limited	None	Compete with benthophagic fish
Ictiobus bubalus	Larger streams and lakes	80% macro and microinvertebrates, 20% algae and vascular plants	Movement into shallows	More abundant	40 lbs.	Limited	None	Compete with benthophagic fish
Carpiodes carpio carpio	Large, turbid rivers; lakes, ponds	Insects, molluscs, entomostracans, algae, protozoa, bottom ooze		Abundant in some areas	2 lbs.	Little, poor quality food		Compete with benthophagic fish
Cyprinus carpio	All habitats; prefer weak currents and mud bottom	Omnivorous: insects, plants, other invertebrates, organic debris; prefer animal food	Variable migrations; nomadic; migrate to shallows to spawn	Very abundant	Up to 20 lbs. common	Low price, but large quantity makes fish valuable	Some sport fishing	Increase turbidity, compete with benthophagic fish
Notemigonus crysoleucas	Lakes, ponds, streams; prefer weak currents, vegetated areas, mud and debris bottom	Omnivorous		Very abundant	15-25 cm	Bait fish	Bait fish	Forage
Pimephales notatus	Lakes and streams of all sizes; most abundant in small and medium sized streams with firm bottom	Omnivorous		Abundant	9 cm	Bait fish	Forage fish	Forage
Pimephales vigilax	All streams	Omnivorous		Very abundant; more abundant in larger rivers than P. notatus	8 cm	Bait fish	Forage fish	Forage
Hybognathus nuchalis	Large and small rivers, silty rivers and backwater areas over mud bottom	Mud feeder; only eats algae	Migrate to quiet water to spawn	Abundant	10 cm	None	Forage fish	Forage
Notropis lutrensis	Large streams	Algae, insects, crustaceans		Abundant	6 cm	None	Forage	Forage
Notropis atherinoides	Open water of larger lakes and rivers with clean bottom	Entomostraca, some algae, terrestrial insects		Abundant	10 cm	Bait fish	Forage	Forage
Hybopsis storeriana	Larger lakes and rivers; prefer gravel bottom	Mayflies, chironomids, amphipods	Moves into creeks to spawn	Common	20 cm	None	None	Forage
Fundulus notatus	Lakes and streams; prefer weedy areas, mud, detritus bottom; usually at surface	Insects, some filamentous algae, amphipods and entomostraca		Common	8 cm	None	Forage	Forage
Gambusia affinis	Quiet waters of lakes and streams			Common	5 cm	None	Limited value as forage	Forage
Labidesthes sicculus	Open water, lakes and streams; at surface	Aquatic insects, entomostraca		Common	8 cm	None	Limited value as forage	Forage
[illegible]	Shallow, eutrophic	Insects, fish, crusta-	Move into shallow	Abundant	1.25 m	Valuable	Rough fish;	Compete with

139

B

Table 10. Ecology of the fishes recorded as present, St. Louis, Missouri, to Cairo, Illinois.

ity	Abundance	Size	Commercial importance	Sport importance	Relationship with other fish	Current requirements	Turbidity requirements	Dissolved oxygen requirements	Special requirements	Spawning time	Spawning site
al- to	Frequently abundant	1 1/2'-2' (3')	None; can be eaten with correct preparation	Good fighting	Detrimental; voracious predator	Tolerate current	Prefer clear water	Can breathe air		Late spring	Quiet water with vegeta tion and debris; 2-3' deep; vegetation "nest nest in colonies
ws	Abundant	2.2 m	None	Good fighting	Predator	Prefer stagnant water		Can breathe air		Late spring	Shallow water among grass and weeds
ded am	Abundant	2.5 m	None	Good fighting	Predator	Prefer sluggish water		Can breathe air		Late spring to summer	Shallow water (1-3') with weeds; often in flooded areas
	Rare	1-2 m	Valuable food	None		Tolerant		Skin respiration		Summer; begin migration in early spring	Atlantic Ocean
	Rare	0.4 m	None; poor food fish	Some game value where abundant; will take artificial lure		Prefer swift water	Tolerant		Not tolerant to pollution	Early spring	Shallow areas
	More common than H. alosoides		None	Game fish, will take artificial lure			Less tolerant		Not tolerant to pollution	Early spring	Shallow areas
ls- pawn- r in	Very abundant	.25 m	None	Forage	Forage	Tolerant	Tolerant		Tolerant of salinity, cannot withstand prolonged low temperature	Mid spring to summer	Shallow areas of lakes, rivers, sloughs
ion	Up to 600 lbs. per acre	1 m 50 lbs.	Limited	None	Compete with benthophagic fish	Prefer quiet water	Tolerant			Mid April to May	Sloughs and flooded la over grass and vegetation or mud
	More abundant	40 lbs.	Limited	None	Compete with benthophagic fish	Prefer sluggish or standing water	Tolerant			Mid April to May; requires rising water	Sloughs and flooded la over grass and vegetation or mud
	Abundant in some areas	2 lbs.	Little, poor quality food		Compete with benthophagic fish	Prefer sluggish water	Tolerant			April to June	Randomly distribute eggs
mi- ws	Very abundant	Up to 20 lbs. common	Low price, but large quantity makes fish valuable	Some sport fishing	Increase turbidity, compete with benthophagic fish	Tolerant	Tolerant	Tolerant		Spring through summer	Marshes, flooded land, shallow areas; eggs scattered at random over vegetation rubble and debris
	Very abundant	15-25 cm	Bait fish	Bait fish	Forage	Tolerant	Tolerant	Tolerant		May to August	Quiet areas; beds of vegetation and mats of filamentous algae
	Abundant	9 cm	Bait fish	Forage fish	Forage	Wide tolerance, prefer quiet water	Wide tolerance			May to August	Under surface of various objects in shallow water or over gravel or sand bottom
	Very abundant; more abundant in larger rivers than P. notatus	8 cm	Bait fish	Forage fish	Forage	Prefer rapid current				Late May to August	
t	Abundant	10 cm	None	Forage fish	Forage	Tolerant	Tolerant			May to August, intermittent spawner	Calm water near shore; lays eggs on bottom ooze
	Abundant	6 cm	None	Forage	Forage	Wide tolerance	Wide tolerance			May to October	Newly flooded weedy are in lakes and rivers
	Abundant	10 cm	Bait fish	Forage	Forage	Prefer current	Tolerant			Mid May to August	Near surface in open water
ks	Common	20 cm	None	None	Forage	Tolerant	Tolerant			June to July	In creeks or open water
	Common	8 cm	None	Forage	Forage	Prefer weak current	Tolerant			Late May to June	Weed-filled shorelines
	Common	5 cm	None	Limited value as forage	Forage	Tolerant; prefer quiet water	Tolerant			May to September, more than 1 brood/season	Viviparous
	Common	8 cm	None	Limited value as forage	Forage	Tolerant				June	Shoal areas, frequently with current
		1.25 m	Valuable	Rough fish;	Compete with	Tolerant	Tolerant, pre-	Fairly high		May to June	No specific require-

B

C

...as present, St. Louis, Missouri, to Cairo, Illinois.

...hip ...r	Current requirements	Turbidity requirements	Dissolved oxygen requirements	Special requirements	Reproduction: Spawning time	Spawning site	Eggs	Hatching time	Young	Maturity
...al; ... pre-	Tolerate current	Prefer clear water	Can breathe air		Late spring	Quiet water with vegetation and debris; 2-3' deep; vegetation "nest", nest in colonies	Adhesive; adhere to plant roots; 2000-5000/nest	8-10 days; leave nest in 9 days	School	4 years
	Prefer stagnant water		Can breathe air		Late spring	Shallow water among grass and weeds	Up to 77,000 deposited on vegetation; adhesive; poisonous	3-9 days	Rapid growth, 6-8" in first year	4-6 years
	Prefer sluggish water		Can breathe air		Late spring to summer	Shallow water (1-3') with weeds; often in flooded areas	Adhesive; withstand dessication	8-9 days	5-6" after first year	
	Tolerant		Skin respiration		Summer; begin migration in early spring	Atlantic Ocean	10 million			2 years
	Prefer swift water	Tolerant		Not tolerant to pollution	Early spring	Shallow areas	14,000; semi-buoyant		15 cm after first year	2-4 years
		Less tolerant		Not tolerant to pollution	Early spring	Shallow areas			15 cm after first year	
	Tolerant	Tolerant		Tolerant of salinity, cannot withstand prolonged low temperature	Mid spring to summer	Shallow areas of lakes, rivers, sloughs	400,000; demersal and adhesive	36-100 hours	15 cm after first year; school	1-3 years
... with ...agic	Prefer quiet water	Tolerant			Mid April to May	Sloughs and flooded land over grass and vegetation or mud	Adhere to vegetation 400,000 from 10-lb. female	8-14 days	17 cm after first year	3 years
... with ...agic	Prefer sluggish or standing water	Tolerant			Mid April to May; requires rising water	Sloughs and flooded land over grass and vegetation or mud	Adhere to vegetation 400,000 from 10-lb. female	8-14 days	17 cm after first year	3 years
... with ...agic	Prefer sluggish water	Tolerant			April to June	Randomly distribute eggs	100,000	8-12 days	3-5" in first year	2-3 years
... tur- compete ...tho- fish	Tolerant	Tolerant	Tolerant		Spring through summer	Marshes, flooded land, shallow areas; eggs scattered at random over vegetation rubble and debris	39,000-2,000,000	3-20 days	5" by end of first summer, 1 lb. after first year	2-4 years
	Tolerant	Tolerant	Tolerant		May to August	Quiet areas; beds of vegetation and mats of filamentous algae	Adhesive			1 year
	Wide tolerance, prefer quiet water	Wide tolerance			May to August	Under surface of various objects in shallow water or over gravel or sand bottom	2,000/year	7-14 days		
	Prefer rapid current				Late May to August					
	Tolerant	Tolerant			May to August, intermittent spawner	Calm water near shore; lays eggs on bottom ooze	Average of 3,000; non-adhesive			1 year
	Wide tolerance	Wide tolerance			May to October	Newly flooded weedy areas in lakes and rivers			4 cm after first year	1 year
	Prefer current	Tolerant			Mid May to August	Near surface in open water		24 hours		
	Tolerant	Tolerant			June to July	In creeks or open water	11,000		4 cm after one year	
	Prefer weak current	Tolerant			Late May to June	Weed-filled shorelines	"Thrown" into vegetation	24 days	5 cm after one year	
	Tolerant; prefer quiet water	Tolerant			May to September, more than 1 brood/season	Viviparous	1-315/season			1 year
	Tolerant				June	Shoal areas, frequently with current	Float until contact with object, then adhere		School; adult size in 1 year	1 year
...ith	Tolerant	Tolerant, pre-	Fairly high		May to June	No specific require-	Pelagic	25-30 hours	School;	3-7 years

Notropis lutrensis	Large streams	Algae, insects, crustaceans		Abundant	6 cm	None	Forage	Forage
Notropis atherinoides	Open water of larger lakes and rivers with clean bottom	Entomostraca, some algae, terrestrial insects		Abundant	10 cm	Bait fish	Forage	Forage
Hybopsis storeriana	Larger lakes and rivers; prefer gravel bottom	Mayflies, chironomids, amphipods	Moves into creeks to spawn	Common	20 cm	None	None	Forage
Fundulus notatus	Lakes and streams; prefer weedy areas, mud, detritus bottom; usually at surface	Insects, some filamentous algae, amphipods and entomostraca		Common	8 cm	None	Forage	Forage
Gambusia affinis	Quiet waters of lakes and streams			Common	5 cm	None	Limited value as forage	Forage
Labidesthes sicculus	Open water, lakes and streams; at surface	Aquatic insects, entomostraca		Common	8 cm	None	Limited value as forage	Forage
Aplodinotus grunniens	Shallow, eutrophic lakes, large rivers and tributaries	Insects, fish, crustacea; primarily benthophagic	Move into shallow water in spring, return to deeper water in fall	Abundant	1.25 m 20-25 kg avg. 1-2 kg	Valuable	Rough fish; will take bait or lure	Compete with benthophagic fish
Ictalurus natalis	Ubiquitous; most abundant in larger streams	Omnivorous; insects, fish, also scavenger		Abundant	1 kg	Little	Fair, good quality meat	Compete with benthophagic fish
Ictalurus punctatus	Lakes, rivers, streams	Benthic insects, fish, filamentous algae	Nomadic	Abundant	10 kg usually 2.2 kg	High	High	
Ictalurus furcatus	Large streams; rarely in lakes and small streams	Primarily piscivorous; some large crustaceans	Move into flooded area during water, downstream in winter	Common	60 kg 10-12 kg common	High	High	
Pylodictus olivaris	Large rivers, tributaries, and backwaters	Piscivorous	Homing and nest-seeking, migrate into tributaries	Rare to common	20 kg	Limited	Limited	Predator
Morone chrysops	Deep, standing water, lower portions of rivers	Fish, insects, crustaceans	Move freely in schools; upstream in spring to spawn	Abundant	1.5 kg 45 cm		Good	Predator
Micropterus salmoides	All waters, most abundant in lakes	Primarily piscivorous	Restricted movement	Abundant	6 kg		Good	Predator
Micropterus punctulatus	Prefer streams and rivers (deeper water than *M. salmoides*)			Common	1 kg		Good	Predator
Lepomis cyanellus	Widely distributed, all habitats, weedy areas with mud bottom	Insects, crustaceans, fish		Very abundant in tributaries and extra-channel areas	15-20 cm		Fair	
Lepomis humilis	Streams	Insects, crustaceans, occasionally small fish		Abundant in some areas	10 cm	None	Poor	
Lepomis macrochirus	All warm water areas	Aquatic insects and zooplankton		Abundant	0.5 kg	None	Good	
Lepomis microlophus	Primarily lakes	Aquatic insects, molluscs, filamentous algae, macrophytic vegetation			0.3 kg 15-20 cm	None	Good	
Lepomis megalotis	Large streams, ponds, weedy areas with mud, detritus bottom	Aquatic insects, crustaceans, fish	None	Common	20 cm	None	Good	
Lepomis gulosus	Lakes, streams; all bottom types with or without vegetation	Fish, crayfish, aquatic insects		Rare	25 cm	None	Good	Predator as adult
Pomoxis nigromaculatus	Lakes and streams, weedy areas with mud, debris bottom	Aquatic insects, fish, crustaceans	Random	Abundant	35 cm	None	Good	Predator as adult
Pomoxis annularis	Lakes and streams; mud, debris bottom	Crustaceans, insects, fish	Random	Abundant (more abundant in warmer waters than *P. nigromaculatus*)	30 cm	None	Good	Predator as adult
Dorosoma petenense	Lakes (pelagic zone), streams in current areas	Plankton	Travel in schools	Abundant	10-15 cm	None	Important as forage	Forage
Alosa chrysochloris	Large rivers	Primarily fish	Anadromous in some streams	Rare	1 kg	None	None	Predator
Stizostedion vitreum	Lakes, rivers with hard bottoms	Fish, larger invertebrates	Usually confined to home pool, but may move up or down stream in schools	Common in certain areas	6 kg .6 m		Good	Predator
Stizostedion canadense	Large rivers, lakes, ponds with firm bottom	Fish, insects, crustaceans	Move randomly from home pool	Abundant in certain areas, more abundant than walleye in southern waters	.5 m maximum		Good	Predator

D

	Abundant	6 cm	None	Forage	Forage	Wide tolerance	Wide tolerance			May to October	Newly flooded weedy areas in lakes and rivers	
	Abundant	10 cm	Bait fish	Forage	Forage	Prefer current	Tolerant			Mid May to August	Near surface in open water	
ks	Common	20 cm	None	None	Forage	Tolerant	Tolerant			June to July	In creeks or open water	11
	Common	8 cm	None	Forage	Forage	Prefer weak current	Tolerant			Late May to June	Weed-filled shorelines	" ve
	Common	5 cm	None	Limited value as forage	Forage	Tolerant; prefer quiet water	Tolerant			May to September, more than 1 brood/season	Viviparous	1-
	Common	8 cm	None	Limited value as forage	Forage	Tolerant				June	Shoal areas, frequently with current	Fl wi ad
llow g, er	Abundant	1.25 m 20-25 kg avg. 1-2 kg	Valuable	Rough fish; will take bait or lure	Compete with benthophagic fish	Tolerant	Tolerant, prefer clean water	Fairly high requirement		May to June	No specific requirement; usually shallow open water	Fe
	Abundant	1 kg	Little	Fair, good quality meat	Compete with benthophagic fish	Tolerant, prefer sluggish	Tolerant	Tolerate low dissolved O_2		May to July	.2-1.2 m deep water	20
	Abundant	10 kg usually 2.2 kg	High	High		Tolerant	Tolerant, prefer clear water	Fairly high requirement		May to June	Shallow water in shelter	30
ded ter,	Common	60 kg 10-12 kg common	High	High						April to June		
t- te es	Rare to common	20 kg	Limited	Limited	Predator	Tolerant	Tolerant			May to August	3.5-5 m deep; build nest in secluded water	69 ad
eam pawn	Abundant	1.5 kg 45 cm		Good	Predator	Prefer standing water				April to June	Sandy or rocky shoals with running water	65
e-	Abundant	6 kg		Good	Predator	Prefer sluggish or standing water	Deleterious to nests		Constant temperature important for spawning success	April to June	Shallow water with vegetation or debris	20
	Common	1 kg		Good	Predator	Prefer running water					Shallow water; gravel bottom	
	Very abundant in tributaries and extra-channel areas	15-20 cm		Fair		Prefer weak current	Tolerant	Tolerant		May to August	Nest in shallow, slow water; gravel bottom	
	Abundant in some areas	10 cm	None	Poor		Prefer running water	Tolerant			May to June	Shallow water (18 cm to 1 m)	15,
	Abundant	0.5 kg	None	Good		Prefer quiet water	Require clear water	Semi-tolerant of low O_2		May to June	Shallow water; sand, gravel, mud, debris bottom	23
		0.3 kg 15-20 cm	None	Good		Prefer quiet water	Require clear water		Sudden temperature fluctuations deleterious	May to September (may spawn more than once a year)	Shallow water; build nest on sand, gravel, or mud	24
	Common	20 cm	None	Good		Tolerant				May to August	Shallow water, slow to moderate current, hard substrate	Ad or
	Rare	25 cm	None	Good	Predator as adult	Tolerant, prefer weak current	Tolerant	Tolerant		June to July	0.15-1.6 m deep; nest built near rubble; tolerate light silt bottom	
	Abundant	35 cm	None	Good	Predator as adult	Prefer weak current	Prefer clean water			May to June	.1-6 m deep	Att veg roc 137
	Abundant (more abundant in warmer waters than *P. nigromaculatus*)	30 cm	None	Good	Predator as adult	Prefer weak current	More tolerant than *P. nigromaculatus*			May to June	1-6 m deep	Att veg roc 213
ols	Abundant	10-15 cm	None	Important as forage	Forage	Tolerant	Tolerant		Temperature above 7°C	Spring	Surface	670
some	Rare	1 kg	None	None	Predator	Tolerant	Tolerant			Early spring		
ed to may n ols	Common in certain areas	6 kg .6 m		Good	Predator	Tolerant	Tolerant			Early spring	.7-1.3 m, deep water over rock or gravel shoals	23, eg of
from	Abundant in certain areas, more abundant than walleye in southern waters	.5 m maximum		Good	Predator	Prefer running water	Tolerant; more tolerant than walleye			Early spring	.5-1.3 m, sand shoals	23, eg of

E

rent				August	water				
Tolerant	Tolerant			June to July	In creeks or open water	11,000		4 cm after one year	
Prefer weak current	Tolerant			Late May to June	Weed-filled shorelines	"Thrown" into vegetation	24 days	5 cm after one year	
Tolerant; prefer quiet water	Tolerant			May to September, more than 1 brood/season	Viviparous	1-315/season			1 year
Tolerant				June	Shoal areas, frequently with current	Float until contact with object, then adhere		School: adult size in 1 year	1 year
Tolerant	Tolerant, prefer clean water	Fairly high requirement		May to June	No specific requirement; usually shallow open water	Pelagic	25-30 hours	School: 5" after one year	3-7 years
Tolerant, prefer sluggish	Tolerant	Tolerate low dissolved O_2		May to July	.2-1.2 m deep water	2000-7000	5-10 days	School; 3" in first year	3 years
Tolerant	Tolerant, prefer clear water	Fairly high requirement		May to June	Shallow water in shelter	3000-8000	6-10 days	School; remain in shallows	5 years
				April to June					
Tolerant	Tolerant			May to August	3.5-5 m deep; build nest in secluded water	6900 -11,300; adhesive	6-7 days	0.2 m in first year	3-5 years
Prefer standing water				April to June	Sandy or rocky shoals with running water	650,000-970,000	46 hours	10-12 cm in first year	2 years
Prefer sluggish or standing water	Deleterious to nests		Constant temperature important for spawning success	April to June	Shallow water with vegetation or debris	2000-25,000	9-10 days, guarded by male	School when hatch; remain in weedy areas, 10-15 cm	1-3 years
Prefer running water					Shallow water; gravel bottom			15 cm in first year	2 years
Prefer weak current	Tolerant	Tolerant		May to August	Nest in shallow, slow water; gravel bottom			Remain in weeds; 2-7 cm in first year	1 year
Prefer running water	Tolerant			May to June	Shallow water (18 cm to 1 m)	15,000-58,000			3 years
Prefer quiet water	Require clear water	Semi-tolerant of low O_2		May to June	Shallow water; sand, gravel, mud, debris bottom	2360-49,400	32 hours at 22°C		2-3 years
Prefer quiet water	Require clear water		Sudden temperature fluctuations deleterious	May to September (may spawn more than once a year)	Shallow water; build nest on sand, gravel, or mud	2400			
Tolerant				May to August	Shallow water, slow to moderate current, hard substrate	Adhere to stones or roots			3 years
Tolerant, prefer weak current	Tolerant	Tolerant		June to July	0.15-1.6 m deep; nest built near rubble; tolerate light silt bottom			5 cm in first year	1-2 years
Prefer weak current	Prefer clean water			May to June	.1-6 m deep	Attach eggs to vegetation or roots; 30,000-137,000			2-3 years
Prefer weak current	More tolerant than P. nigromaculatus			May to June	1-6 m deep	Attach eggs to vegetation or roots; 970-213,213			2-3 years
Tolerant	Tolerant		Temperature above 7°C	Spring	Surface	6700-12,400	3 days	Grow 2.5 cm per month	6 months
Tolerant	Tolerant			Early spring				8-10 cm in one year	
Tolerant	Tolerant			Early spring	.7-1.3 m, deep water over rock or gravel shoals	23,000-50,000 eggs per pound of fish weight	12-18 days	15 cm in first year	2-3 years
Prefer running water	Tolerant; more tolerant than walleye			Early spring	.5-1.3 m, sand shoals	23,000-50,000 eggs per pound of fish weight	12-18 days	Up to 10 cm in first year	3-4 years

E

F

Table 11. Current requirements of adult fish.[1]

Fast current	Tolerant	Slack current
	Amia calva	→
	Lepisosteus osseus	→
	Lepisosteus platostomus	→
	Anguilla rostrata	→
←	*Hiodon alosoides*	
	Hiodon tergisus	
	Dorosoma cepedianum	
	Ictiobus cyprinellus	→
	Ictiobus bubalus	→
	Carpiodes carpio	→
	Cyprinus carpio	
	Notemigonus crysoleucas	
	Pimephales notatus	
←	*Pimephales vigilax*	
	Hybognathus nuchalis	
	Notropis lutrensis	
	Notropis atherinoides	
	Hybopsis storeriana	
←	*Fundulus notatus*	
	Gambusia affinis	→
	Labidesthes sicculus	→
	Aplodinotus grunniens	
	Ictalurus natalis	
←	*Ictalurus furcatus*	
←	*Ictalurus punctatus*	
	Pylodictus olivaris	
	Morone chrysops	→
	Micropterus salmoides	→
←	*Micropterus punctulatus*	
	Lepomis cyanellus	→
←	*Lepomis humilus*	
	Lepomis macrochirus	→
	Lepomis microlophus	→
	Lepomis megalotis	
	Lepomis gulosus	→
	Pomoxis nigramaculatus	→
	Pomoxis annularis	→
	Dorosoma petenense	
	Aloso chrysochloris	
	Stizostedion vitreum	→
←	*Stizostedion canadense*	

[1] Arrows indicate the preferred habitat.

Table 12. Current requirements for spawning.[1]

Flowing water	Tolerant	Slack water
		*Amia calva**
		*Lepisosteus osseus**
		*Lepisosteus platostomus**
	Hiodon alosoides →	→
	Hiodon tergisus →	→
	Dorosoma cepedianum →	→
		*Ictiobus cyprinellus**
		*Ictiobus bubalus**
	Carpoides carpio →	→
		*Cyprinus carpio**
		*Notemigonus crysoleucas**
		Pimephales vigilax
		Pimephales notatus
		Hybognathus nuchalis
		*Notropis lutrensis**
	Notropis atherinoides	
←	← *Hybopsis storeriana*	
		*Fundulus notatus**
		Gambusia affinis
Labidesthes sicculus →	→	
	Aplodinotus grunniens	
		Ictalurus natalis
		*Ictalurus punctatus**
		*Pylodictus olivaris**
		*Micropterus salmoides**
		Micropterus punctulatus
		Lepomis cyanellus
		Lepomis humilus
		Lepomis macrochirus
		*Lepomis gulosus**
		*Pomoxis nigromaculatus**
		*Pomoxis annularis**
Morone chrysops		
	Dorosoma petenense	
←	← *Stizostedion vitreum*	
←	← *Stizostedion canadense*	

[1] Arrows indicate the preferred spawning habitats.

*Also requires vegetation.

Table 13. Effects of loss of backwater chutes.
A. Fish adversely affected by loss of backwater.

Amia calva P	*Ictalurus natalis* S
Lepisosteus osseus P	*Ictalurus punctatus* (?) C,S
Lepisosteus platostomus P	*Pylodictus olivaris* C,S
Dorosoma cepedianum F	*Morone chrysops* S
Ictiobus cyprinellus	*Micropterus salmoides* S
Ictiobus bubalus	*Micropterus punctulatus* S
Carpiodes c. carpio C,S	*Lepomis humilus* S
Notemigonus crysoleucas F	*Lepomis cyanellus* S
Pimephales notatus F	*Lepomis macrochirus* S
Hybognathus nuchalis F	*Lepomis microlophus* S
Notropis lutrensis F	*Pomoxis nigramaculatus* S
Fundulus notatus F	*Pomoxis annularis* S
Gambusia affinis F	*Stizostedion vitreum* S
Aplodinotus grunniens (?) C,S	*Stizostedion canadense* S

C = Commercial importance
F = Important for forage
P = Predatory species
S = Sport importance

Table 13. Effects of loss of backwater chutes.
B. Fish not affected by loss of backwater areas.

Notropis atherinoides F	*Pylodictus olivaris* C,S
Hybopsis storeriana F	*Micropterus punctulatus* S
Labidesthes sicculus F	*Lepomis humilus* S
Aplodinotes grunniens C,S	*Lepomis megalotis* S
Ictalurus punctatus C,S	*Lepomis gulosus* S
Ictalurus furcatus C,S	*Pomoxis annularis* S
Hiodon alosoides S(?)	*Dorosoma petenense* F
Hiodon tergisus S(?)	*Alosa chrysochloris*
Carpiodes c. carpio C(?)	*Stizostedion canadense* S
Pimephales notatus F	*Stizostedion vitreum* S
Pimephales vigilax F	

C = Commercial importance

F = Important for forage

S = Sport importance

In accordance with ER 70-2-3, paragraph 6c(1)(b), dated 15 February 1973, a facsimile catalog card in Library of Congress format is reproduced below.

Illinois. Southern Illinois University, Carbondale.
Fisheries Research Laboratory.
Study of importance of backwater chutes to a riverine fishery; final report, by H. L. Schramm, Jr. [and] W. M. Lewis. Vicksburg, U. S. Army Engineer Waterways Experiment Station, 1974.
144 p. illus. 27 cm. (U. S. Waterways Experiment Station. Contract report Y-74-4)
Prepared for U. S. Army Engineer District, St. Louis, St. Louis, Missouri, under contract No. DACW39-73-C-0015.
References: p. 85-96.

1. Aquatic biology. 2. Backwater areas. 3. Environmental impact. 4. Fishes. 5. Mississippi River. 6. Rivers. I. Schramm, Harold L. II. Lewis, William M., joint author. III. U. S. Army Engineer District, St. Louis. (Series: U. S. Waterways Experiment Station, Vicksburg, Miss. Contract report Y-74-4)
TA7.W34c no.Y-74-4